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Science in the Context of Technology

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In Martin Carrier and Alfred Nordmann (eds.)
Science in the Context of Application
Dordrecht: Springer, 2010, pp. 317-336

Despite its ambitious title, this is a very small contribution to a very big theme. The big theme is the 'Philosophy of Technoscience' – what it is, what it finds, and why it is needed. Even though most agree that every field of research calls for investigations of its particular history and specific methodology, there is pervasive agreement also that these investigations can sensibly join together under the heading 'philosophy of science.' The call for a philosophy of technoscience shoulders a considerable burden of proof. It must show that investigations of the special sciences and technosciences can sensibly join together also under this heading. In order to show this it must establish, by using examples but also in a principled manner, that there is a meaningful difference between 'science' and 'technoscience' such that the philosophy of technoscience brings fruitful questions of its own to the various particular fields of research.

Some consider it a problem of classification whether there is a meaningful difference between science and technoscience. They require a set of criteria by which entire fields of research or specific activities can be classified as either scientific or technoscientific. Should unambiguous allocation of one activity to science and another to technoscience turn out to be a difficult task, this would suggest that there was no meaningful difference to start with.[1] But the problem is not necessarily one of classification but can also be viewed as one of interpretation. In this case, the very idea of 'science' serves to guide and orient research activities, and 'technoscience' then provides another kind of orientation, even if the particular laboratory practices look the same in

[1] A variant to this approach is being pursued by Bernadette Bensaude-Vincent, Astrid Schwarz and the author of this chapter – to classify not researchers, research fields or activities but to investigate the different objects of research, their genesis and ontology.

both cases. Moreover, in this case 'science' and the 'philosophy of science' provide an opportunity for researchers to reflect in a particular way on their own work and its place in history. Perhaps, 'technoscience' and the 'philosophy of technoscience' offer much-needed novel opportunities for researchers to reflect on their own work and its place in the social order. These novel opportunities are much-needed today not because the research activities themselves have changed in a drastic way but simply because self-reflection in terms of 'science' does not work as well as it used to.

It is here that the small contribution comes in. It concerns 'science' and 'technoscience' as interpretive concepts and whether they can be associated with historical epochs or eras. Might it be that 'science' has served the self-reflection of natural philosophers and scientists in the age of Enlightenment roughly from the late-18th to the mid-20th centuries, and might it be that contemporary research since, say, the 1990s is better served by the notion 'technoscience'? In particular, what arguments would be sufficient to establish that we are now living in an age of technoscience? These questions and their answers make a contribution to the philosophy of technoscience mostly in that they underscore its cultural significance. They leave entirely unaffected, however, the main business of the philosophy of technoscience, namely its epistemological questions regarding technoscientific knowledge and objectivity or its ontological questions regarding the constitution and character of technoscientific research objects.

Indeed, some might argue that it is misleading even to contemplate the question of an epochal break that separates the age of technoscience from an age of science. The term 'technoscience' was introduced by Gilbert Hottois and popularized by Bruno Latour and Donna Haraway to refer quite generally to knowledge-production in a technological milieu, that is, to the technical context of instruments and experiments and to the technical accomplishment of controlling and predicting phenomena (Hottois 1984, Latour 1987, Haraway 1997).[2] Despite the differences between these authors, none of them suggests that the technosciences are new or that we have recently moved into

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[2] For the history of 'technoscience' as an interpretive concept see Bensaude-Vincent 2009 and Ihde and Selinger 2003. Among philosophers of science, the usage of the term 'technoscience' has suffered from its affiliation especially with Bruno Latour and Donna Haraway. In recent years, however, the term has diffused so far that it can no longer be associated with particular intellectual traditions. Reticence to adopt this term is founded on a particular suspicion: 'Technoscience' implies a dissociation from an idealized 'science' and thereby casts doubt on the pertinence of the values associated with science – the values associated with Enlightenment, Mertonian norms, critical rationalism, disinterested truth-seeking, theoretical representation of how things really are etc. The suspicion is that the choice of 'technoscience' as the more appropriate interpretive concept amounts to its endorsement and thereby also to a triumphant rejection of the values of science that are now exposed as being obsolete. (This suspicion has been articulated especially by Elzinga 2004.) However, rather than celebrate a postmodern age of technoscience, the philosophy of technoscience attempts to understand what kind of knowledge can be produced and validated within a technoscientific research culture. It aims to articulate the epistemic and social values that characterize knowledge production once the orientation towards the values of 'science' fades away. It thereby produces a notion of 'technoscience' that is no less idealized and mythical than that of 'science' – and it may well do so with a sense of what is lost and ought to be recovered from the history of science as a social institution of public criticism and Enlightenment.

an age of technoscience. Instead, they urge that it is important to consider ‘science and technology’ – but not in the manner in which they are juxtaposed and reflected by the philosophy of science, but in the manner in which they come together as technoscience. The following pages add to this only the question of why it is that Hottois, Latour, and Haraway consider it so urgent or appropriate now to shift from the perspective of the philosophy of science to that of the philosophy of technoscience. Apparently, there is something about our current situation that prompts these three and many others to call into question a powerful set of ideas according to which all the diverse sciences are dedicated to the search for truth, that this search advances general Enlightenment, and that the sciences are therefore characterized by a ‘critical’ attitude not just towards their own hypotheses but also towards the presuppositions that inform policies and social debate. By calling these ideas into question, the theorists of technoscience proclaim that there was a time when these ideas had considerable traction, even where the practice of science did not live up to them. They also proclaim that this time is gone and that another set of ideas has effectively displaced them.

What arguments would be sufficient to establish that we are now living in an age of technoscience? A brief clarification of what is and what is not meant by “technoscience” will be followed by general historiographic considerations of what it takes to argue for an epochal break of any kind. After specifying what kind of argument might be required, I will highlight two strategies by which the philosophy of technoscience can make a case for the age of technoscience.

I. What is the meaning of technoscience?

Without reconstructing in detail how the term has been used by Gilbert Hottois, Bruno Latour, Donna Haraway, Raphael Sassower, Don Ihde, Bernadette Bensaude-Vincent, and many others, it is possible to identify a few defining features of technoscience and to say accordingly what it is not: It is not applied science, engineering, or engineering science. And it is not commercialized or entrepreneurial science or science that is done for the sake of utility rather than curiosity. ‘Technoscience’ is not a disciplinary label that picks out a subset of the sciences, nor is it ‘science’ formed or deformed by extraneous intentions, interests, or application pressures.

As mentioned above, Gilbert Hottois coined the term in 1984 and used it to refer to science that is done in a technological setting or milieu and that is technology-driven (Hottois 1984). He thus uses the term technoscience much like one uses the word technomusic where the sounds cannot be separated – as in a musical score – from the technological context in which they were produced. Along these lines, Bruno Latour introduced the term initially as shorthand for and fusion of ‘science-and-technology,’ that is, as a technology/science hybrid where the two cannot be separated out from one another in terms of basic and applied research (Latour 1987).

According to these definitions ‘technoscience’ is an alternative to ‘science and technology’ with its assumption of two distinct but related spheres. Hottois, Latour, and other philosophers of technoscience do not presuppose, however, that science and technology were ever actually distinct – indeed, they are always bound up with one another. They observe instead that philosophers and scientists have invested a lot of intellectual effort into separating them out – to put science here and technology there, nature here and culture there, representation of a given world here and intervention into the lifeworld there, pure theoretical knowledge here and impure social utility there. The conceptual work of separating out these interrelated domains has been called a work of purification. While this work was more or less successful during the age of science and technology, one might say that we encounter technoscience when this work of purification is abandoned because it proves impossible or unnecessary.[3]

Picking up on the first half of this definition, one can define technoscience as a kind of research where theoretical representation and technical intervention cannot be held apart even in thought. In the case of laboratory experiments this means that scientists look at an experiment and distinguish their own contribution from that of nature: the laboratory scientists provide hypotheses, instrumental apparatus, and an experimental set-up, nature then steps in to produce the observed phenomenon or effect. While it is possible to maintain this distinction in many cases, it is sometimes extremely difficult, if not impossible, because the observed phenomena and effects also appear to be engineered – when one studies the ‘natural’ behaviour of genetically engineered organisms, for example. This difficulty might serve as a criterion to distinguish technoscience from science.

According to the second half of the previous definition, we encounter technoscience when the work of purification is not pursued because it appears unnecessary. Accordingly one can define it in terms of ‘ontological indifference’[4]: technoscientific research is that kind of research that has no need to distinguish between the contributions of nature and of technology in the creation of a phenomenon. If the purpose of research is to determine what is and or isn’t really the case, it is

[3] Modern philosophy of science from Kant, Hertz, Mach, Poincaré, and Wittgenstein via the Vienna Circle to contemporary philosophers like Michael Dickson defines good science in terms of critical awareness of the ways in which its formalisms – broadly conceived to include concepts and experimental methodology – structure and shape the phenomena. According to Dickson, for example, a good theory is formulated in such a way that its formal apparatus transparently delineates its empirical content (Dickson 2006). Technoscience designates a technologically complex condition where this critical awareness cannot be achieved or where successful research does not require it.

[4] The term has been suggested by Peter Galison to characterize a kind of physics that is interested in making and building rather than understanding the hierarchical composition of material reality (Galison 2006).

crucial to know what is the case independently of what humans think and do. If the purpose of research is to show what can be done, it usually makes little sense even to juxtapose natural agency and human intervention. Showing what can be done characterizes not only the engineering sciences but more generally "an engineering way of being in science" or "research in a design mode" (Galison 2006, Ann Johnson in conversation, Nordmann forthcoming). These designations might therefore serve as equivalents to 'technoscience.'[5]

II. EPOCHAL BREAK ARGUMENTS

The previous suggestions of how to distinguish science and technoscience do not imply that the technosciences are a recent phenomenon that somehow supersedes the sciences. On the contrary, they have coexisted and continue to coexist: science then and now includes cosmology, evolutionary biology, physiology, game theory, and technoscience then and now encompasses pharmacy, synthetic chemistry, medical and agricultural research, and nanotechnology. Moreover, in physics, chemistry, molecular biology, computer science, some of the research can be considered scientific, other endeavours are properly described as technoscientific. This contemporaneity of science and technoscience is generally acknowledged by placing Francis Bacon as a "founding father" of technoscience side by side with Galileo, Newton, or Lavoisier as patron saints of science. Thomas Kuhn relates this to the parallel development of "Mathematical versus Experimental Traditions in Western Science" and noted also the intellectual prestige and dominance in many fields of the mathematical tradition in the 19th and 20th centuries – mathematization became the hallmark of the higher ranking pure and fundamental sciences as opposed to the applied sciences (Kuhn 1977, 61).

Despite the contemporaneity of the theoretical sciences in the mathematical tradition and the creative technosciences in the experimental tradition it is possible to posit a momentous epochal break on the basis of Kuhn's account: If the dominance of the mathematical tradition characterized an age of science, the experimental tradition has gained, perhaps regained the upper hand in the current age of technoscience. But in order to actually establish such a claim, historiographic and methodological considerations are required to clarify what an epochal break is and how one can argue for it. These considerations cannot be provided here, since they call for systematic reflection

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[5] Even without referring to "entrepreneurial" or "venture science" (Etzkowitz 2003, Rajan 2006) , post-academic or post-normal science (Ziman 2000, Funtowicz and Ravetz 1990), let alone "mode-2 research" (Gibbons et al. 1994, Nowotny et al. 2001), this brief discussion offered too many and not too few definitions of technoscience. It is one the tasks of a philosophy of technoscience to sort through these various determinations and to evaluate whether and how they mutually support one another.

on the ways to discern and distinguish historical continuity and discontinuity. For present purposes, two central propositions must suffice.

First, the interest in epochal breaks is not at all self-evident but characteristic of a modern conception of history. As Hans Blumenberg has pointed out, there would be no modern world without the assumption of an epochal break, namely the one that separates it from the dark ages (Blumenberg 1983). Of course, the historiography of modernity is full of uncertainty and controversy about the precise time and place, the extent and significance of the break between the medieval period and the modern world. To be modern is nevertheless to frame one's own place in the world historically, part of a movement from one era to the next, each with its own character and destiny. In other words, to be modern is to distinguish oneself, to acknowledge the significance of one's age, and to answer the call of the day. And even as the moderns remained profoundly unsure how they could and should distinguish themselves, they liberally proclaimed epochal breaks, most prominently perhaps in the philosophies of Comte, Hegel, or Marx. A certain conception of history with its eras or epochs served as an instrument of the moderns to reflect upon and interpret themselves, their place in history and thus of their responsibility. There is no compulsion from facts or principle that would force anyone to see an epochal break here or there; but to see an epochal break is tantamount to accepting a historical mission, and this is what moderns do.[6]

Blumenberg's insight has an important implication for the epochal break under consideration. Especially Paul Forman pointed out that the transition from the age of science to the age of technoscience coincided with the transition from modernism to postmodernism (Forman 2007).[7] If one takes this observation seriously, one may find that the age of science was wedded to the modern conception of history with its interest in epochal breaks and the vocation or historical calling of the scientist. Accordingly, to be a scientist was to accept a historical mission which has been described as an unending quest for the unachievable, yet guiding ideal of truth (Popper 1976, Weber 1946). In light of Kant's dictum that we do not live in an enlightened age but in an age of enlightenment

[6] The theorist of technoscience Bruno Latour has argued that we have never been modern (Latour 1993). His claim does not contradict Blumenberg's but complements it: Modernity presupposes that one can distinguish the modern self from that of the dark ages, that one can distinguish culture from nature, science from technology, this era from another. According to Latour, since we have never quite succeeded in establishing and fortifying these distinctions, we have never been modern. And yet, it is characteristically modern to engage in such work of purification, that is, in the work of distinguishing oneself, of attributing blame either to nature or to human intervention, etc. And this is precisely Blumenberg's point.

[7] To be sure, Forman does not use the term "technoscience" to characterize this break. Instead, he speaks of the transition from an age of modernism in which technology is subsidiary to science to an age of postmodernism in which science is subsidiary to technology. In contrast to Forman, I would maintain that the coincidence of the shift from modernism to postmodernism and the shift from an age of science to an age of technoscience is part of the phenomenon under considerations but that the one shift does not explain the other: It is not postmodernism's "fault" that science has surrendered its rank and role in respect to technology.

(Kant 1983, 44), it becomes apparent that this historical mission served as the common bond between science and the Enlightenment. In the postmodernist age of technoscience the historical calling of the scientist has lost its rank and role. For technoscience, the business of research has always consisted in the discovery, technical and intellectual control of new phenomena and in the realization of technical possibilities. To be sure and as Bacon demanded, much of this is for the achievement of social benefits, but what these benefits are owes exclusively to current needs and demands – the cure for cancer, the construction of humanoid robots, or the reduction of CO2 emissions. The technosciences expand the pool of technical possibilities and in a piecemeal manner select those to be realized that address current concerns. Attempting to solve the problems of the current world, the technosciences do not take their 'problems' from the remaining gaps in the overarching quest to reach a more perfect theoretical understanding of the world. Due to these different conceptions of history and of the mission of science and of technoscience, the epochal break in question may thus be visible only from one side of the threshold. From the point of view of the age of science, nothing could be more momentous than the transition to an age of technoscience with its apparent abandonment of the human project of general Enlightenment. From the perspective of the age of technoscience, in contrast, there is just technoscientific business as usual since research always served to find solutions to the currently pressing practical problems.[8]

Second, scientific revolutions and paradigm shifts take place in the special sciences and thus within the traditions of science and technoscience; in order to see an epochal break between the age of science and the age of technoscience, one needs to attend to another level of analysis, namely that of the scientific enterprise and the technoscientific regime. Each scientific discipline may have its own paradigm and within each discipline there might be scientific revolutions that involve paradigm shifts. In and of themselves, however, these do not constitute epochal breaks. Accordingly, Blumenberg characterizes paradigm shifts as "a surrender of basic assumptions and the introduction of new elementary suppositions, which get rid of a desperate situation but do not necessarily rupture the identity of the movement of knowledge that had culminated in that situation" (Blumenberg 1983, 16). Another word for the overarching movement of knowledge that leads from one paradigm through some impasse to another is 'scientific enterprise.' It refers to a general movement towards truth which relies on the capacity of the various sciences to distinguish what

[8] This can explain why some philosophers of science see this break and others do not. Those who see it share a somewhat anachronistic affection for modernist conceptions of science as expressed, for example, by the Vienna Circle, Popper, Kuhn, and Lakatos, including their interest in unification programs, rational theory choice, and the like. Those who don't see it view scientific and technoscientific research as a kind of practical and well as conceptual tinkering that is required for the specification of mechanisms or for establishing a local fit between theory, model, and phenomenon.

really is from how things appear to us in the course of conducting our experiments and acting in the world. Analytically, the term 'scientific enterprise' is on a par with terms like 'modernity' or 'the Enlightenment project.' As with modernity and the Enlightenment, one might have a hard time knowing just when and where it began and whether it ended, and still remain confident that the scientific enterprise did not exist everywhere at all times. It is the name for a common project that orients the various sciences and influences their self-definition. And it suggests that, separately or together, all the different ways of knowledge production contribute to a historical process that, citing Max Weber, might be referred to as a process of rationalizing or intellectualizing the world (Weber 1946).

The age of science is characterized by a commitment to the scientific enterprise, and the supposed epochal break would thus consist in its profound transformation or displacement by, say, a technoscientific regime.[9] The scientific enterprise orients the sciences and technosciences of the day towards ideals of truth and understanding but allows for scientific practice to produce along the way many useful things that are, so to speak, exported into the context of application. In contrast, the technoscientific regime seeks to apply not this or that result of scientific research but co-opts the sciences and the scientists as a whole: It draws the scientists with their skills, laboratories, toolsets of theories and methods into the context of application or context of technology. Accordingly, the shift from an age of science to an age of technoscience is something quite different from a profound transformation of science. There are many different sciences, after all, too different to easily accommodate the singular 'science.' Even if 'science' is restricted to the natural sciences, there are physics, chemistry and geography, then there are within physics cosmology and solid state physics, and then there are new formations like molecular biology and bioinformatics. While all these are different sciences, the 'scientific enterprise' and the 'technoscientific regime' designate the larger frameworks within which these various sciences become meaningful and do their work. These notions thus offer what one might call the proper distance from which it is possible to see the epochal change in question. Laboratory studies with their ethnographic methods look too closely at the different sciences and technosciences, and some philosophers of science are assuming a detached vantage point from which they observe strategies of explanation and modelling in general. In contrast, the scientific enterprise appears as the particular historical project to which all the

[9] I use the term 'scientific enterprise' in its ordinary sense. I propose 'technoscientific regime' as a contrasting term largely because 'regime' emphasizes a manner of organizing things in space rather than historical time: the technoscientific regime governs the search for innovative ways of fitting technical and scientific capabilities to particular societal needs and as such for local solutions that can become templates for global action (compare Nordmann 2008).

sciences and the technosciences, no matter how different they are, relate themselves if only by labelling themselves as sciences and claiming a home in the academy. Similarly, within the technoscientific regime all the sciences and technosciences respond to the demand for economic, social, and technical innovation. The notions of 'scientific enterprise' and 'technoscientific regime' thus serve as middle-terms between, on the one hand, the many particular fields of research, each with their own conceptions of science, method and objectivity, and on the other hand, the most general epistemological notions of how humans forge an agreement between their thoughts and the real world.

In summary, then, in order to show that an epochal break separates our current age of technoscience from the previous of age of science one needs to recapture as a thing of the past the notion of the scientific enterprise with its modernist conception of history and its close affiliation with the project of Enlightenment. However, this is not an imaginative exercise alone but shoulders a burden of historical proof: it requires that one can show how the notion of a scientific enterprise actually used to orient the sciences and technosciences in the past and that it has ceased to do so.

III. Epochal Break and Philosophy of Technoscience

There are at least two strategies for recapturing an image of the past and of confronting it with new realities. We can hold two images side by side and find them incommensurable, judging that any transition between them would involve a profound break with the past. We can also follow the movement from one state to the next and find, for example, that one's own age was enabled by some novel question or technique which irrevocably changed the rules of the game, closing off for good any return to the good old days in which that novel question or technique originated. Both strategies have been employed to illustrate profound changes in the general orientation of research. And both strategies challenge the philosophy of technoscience.

a. juxtapositions

The first strategy follows the paradigm of Kuhnian paradigm-shifts by providing detailed reconstructions of two ways of engaging in research. Hans Blumenberg characterizes it as a symmetric comparison of systems or worlds. Here is one world t1, and there is another world t2. One contrasts and compares them and finds them so different that one cannot see the second as merely an extension or further development of the first. This is because things have different meanings in the two worlds. In the words of Blumenberg, by placing them side by side "it soon becomes evident that they cannot have existed side by side" (1983, 31). Their succession, however, appears merely contingent: with this strategy of establishing an epochal break it is impossible to appreciate how one image gives rise to the other and how the age of technoscience originated in the age of science.

The suggestive appeal and the limits of this first strategy can be illustrated by an attempt to contrast scientific and technoscientific cultures of research (Nordmann 2004a).[10] A "culture of research" was defined in terms of three mutually supporting dimensions: a logical or methodological orientation, a corresponding ethos, and its stabilization through social norms. This set the stage for the intended contrast that culminated in the following seven propositions where each offers a technoscientific inversion of a feature of the scientific enterprise:

1. Instead of a commitment in the scientific enterprise to the conceptual and technical distinction of representing and intervening (and thus of science and technology), the age of technoscience is not interested to separate out the theoretical representation of nature and the technical intervention into nature.
2. Instead of producing hypothetically formulated theoretical representations of nature, the age of technoscience sets out to reshape the world as a hybrid of nature and culture.
3. Instead of valorizing quantitative predictions that are highly falsifiable, it is sufficient in the age of technoscience to determine structural patterns in data and to seek qualitative agreements.
4. Instead of articulating lawful regularities or detailing causal mechanisms, research in the age of technoscience is interested in exploring powerful and potentially useful processes and properties.
5. Instead of tending to anomalies and problems as defined by theory, technoscientific research agendas are dedicated to the acquisition of new capabilities – the problems they solve are milestones towards the achievement of a technical goal.
6. Instead of ranked within a hierarchy of nature (from elementary particles to society) and the sciences (from physics to sociology), research activities in the age of technoscience coalesce around transdisciplinary models, methods, and objects.

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[10] Throughout this section I draw on examples from my own work; they are examples of the difficulties encountered in the course of a sustained effort to establish the epochal break in question. – In the case at hand, a second example might have been derived from a paper that considers the role of concepts and theory in the deliberation of novel effects (Nordmann 2004b). Here, it was shown that incommensurable approaches did not prompt controversy or debate in the course of technoscientific research in molecular electronics. The employment of different concepts and theories was ignored for the sake of the shared interest in improving control and performance of an experimental system. This appears striking in contrast to conceptions of controversy and theory-development in the sciences.

7. Instead of distinguishing scientific knowledge of lawful regularities and the (technical) construction of doable things, the technoscientific regime programmatically equates knowing and making, physical possibility and technical feasibility.[11]

For all its imprecision, this dramatic juxtaposition serves not only to indicate the profound difference between two cultures of research or between the values that characterize the ages of science and technoscience. It also challenges the philosophy of science and technoscience to provide rational reconstructions of the two cultures of research. In the case of the scientific enterprise, Karl Popper and Robert Merton led the way to provide a coherent reconstruction that shows how such an idealized, even mythical conception of science can coordinate the research efforts in many disciplines, and how it is reflected in codified styles of writing and experimentation. The current philosophical and sociological literature on technoscience abounds with first attempts to show how the ideals of technoscience also coordinate a great variety of research practices.

b. spaces of possibility

The second strategy follows the movement from one age to the next: it begins in the age of science and follows its progress continuously through time, but more or less suddenly one finds oneself in the very different situation of the age of technoscience. Even on the assumption of continuous development, even allowing that sciences and technosciences have always and will continue to co-exist, the space of possible experience is altered such that the sciences and technosciences are now oriented towards a different overarching agenda than that of the scientific enterprise. This opening of spaces of possibility through the discovery of new modes of reasoning has been described as a Hacking-type revolution (Schweber and Wächter 2000, 584). Examples of this include Lucien Febvre's famous account of Rabelais and the impossibility of unbelief in the 16th century: according to Febvre, it was strictly speaking impossible for Rabelais to be an atheist, due in part to the fact that the French language of his day did not provide him the necessary concepts (Febvre 1982). Whatever led to the formation and availability of these concepts created new possibilities of belief and doubt. Similarly, Hacking argues that one needs a historically specific, economic notion

[11] This list can be continued and has been continued, to be sure. Referring to the four Mertonian norms, for example, the paper "What is Technoscience?" continues as follows: Instead of engaging organized scepticism, technoscientific research adapts the available tool-set of theory to given phenomena and processes. – Instead of maintaining a scientific community of equals (universalism), technoscientific knowledge production involves the collaboration of numerous, unequally situated social actors. – Instead of shared intellectual property (communism), technoscience requires the circulation of products between instrument-builders and laboratories within the triple helix of academia, industry, government. – Instead of disinterestedness and a commitment to truth as the only legitimate interest, technoscience looks neither for better theories nor merely for working devices but acquires and demonstrates basic capabilities. – Ziman (2000), Rajan (2006), and Radder (forthcoming) also revisit the Mertonian ethos of science to illustrate how things have changed.

of a ‘fact’ as a discrete, countable, medium-sized unit in order to encounter the problem of induction as a logical problem of how to aggregate units which do not add up to anything more general than a sum. In this new world of facts thus arose a new philosophical problem, and Hume’s formulation of that problem transformed the philosophical enterprise as a whole: “Hume became possible” – and would not go away (Hacking 2002, 11-14).[12]

Again, one example must suffice to show how the age of science opened a new space of possibility that altered the rules of the game such that even traditional scientific disciplines abandoned their commitment to the scientific enterprise with its work of purification and became oriented, instead, to the regime of technoscience.

With animal models for biomedical research and especially with computer simulations, researchers have at their disposal powerful devices that allow them to study the behaviour of complex systems without understanding how these systems work. Both kinds of models are not properly representations but substitute realities in their own right: their purpose is not to depict certain properties of the natural or original system for which they serve as a substitute, but they are thought to share important behavioural properties with these systems. This sharing of properties underwrites the process of substitution and an entirely new possibility of reasoning.

The following provides an illustration of this new form of reasoning: Rather than offering direct visual access, today’s observational instruments typically generate data and use software to transform this data into a visual output. In parallel to this development, the models of scientists have gained complexity. In order to model or describe a particular situation, simulation modellers utilize formulae and algorithms from a variety of sources, including well-established scientific theory. Computers are needed to calculate these, and these calculations result in many numerical values. Again, software is used to translate these values into a visual output. Now, if the situation to be modelled is one that is observed by a particular instrument, why not create a visual representation of an imagined complex situation that emulates the way in which the instrument would display that situation? And thus one arrives at comparisons of calculated and experimental images which afford a reliable inference from similarity. The similarity of the two images is taken to be explanatory. What was observed in the experiment is attributed to a dynamic process like the one that brought about something very-similar-looking in the simulation. The apparent similarity between the experimental and simulated processes is taken as evidence for the fact that both processes share the same dynamic and partake in the same reality.

[12] The emergence of probability and thus of a whole new class of problems, considerations, possibilities is perhaps more strongly associated with Hacking and especially with his earlier work. *Rewriting the Soul* makes a similar case for memory.

This all too brief and all too superficial presentation of an inference from the similarity of experimental and calculated images suffices to indicate that a new possibility of reasoning has come into being. From the point of view of the philosophy of science, this looks like a superficial and perhaps viciously circular form of inference. However, this may well be a perfectly robust form of reasoning that owes its robustness to the technical milieu in which it originated. This argument from similarity is characteristic of technoscience in that it unfolds in a technical rather than symbolic medium and establishes a measure of technical control. It is constrained and enabled by the technical demands that come with the need to manage complexity and to process vast amounts of information. In particular, it is enabled by the computer as a means not just to make calculations and to create visual images but to instantiate real physical processes. With animal models and computer simulations, the technosciences have at their disposal research instruments that afford complexity and that afford, in particular, the study and control of complex phenomena and their actual dynamics in the medium of the computer or the charted organism.

Numerous challenges for the philosophy of technoscience arise with the availability of research tools that do not serve to establish and represent relations between isolated features but afford the immediate presence and control of complexity (Nordmann 2006). There is first of all the challenge to understand how this might draw the sciences into the regime of technoscience. Their interest in truthfully representing and understanding ever more complex phenomena gave rise to a condition in which the achievement of technical control appears to have become an acceptable and entirely sufficient substitute for theory-development and understanding. Then there is the secondly the rational reconstruction of inferences by analogy which may owe their robustness and reliability precisely to the intellectually intractable mediation by research technologies. This provides thirdly occasion to investigate systematically whether and how the work of purification has really become impossible: especially simulated quasi-natural system behaviours appear to be attributable neither to science and nature nor to technology and culture. Classical conceptions of dispositionality suggest that there is an external, perhaps technical stimulus that is analytically distinct from the self-propelled, spontaneous, natural manifestation of the disposition to respond to the stimulus. Here, it appears to be more appropriate to speak of affordances, that is, of dispositional responses that are themselves engineered to address human interests (Harré 2003). And indeed, the research instruments that afford complexity may also afford the arguments from the similarity of complex systems. Here, then, questions regarding the ontology of technoscientific objects intersect with questions of epistemology and methodology.

Conclusion

None of the arguments and evidences cited so far suffices to substantiate the claim that there was an epochal break between an age of science and an age of technoscience. But they showed how it is possible to argue for such a break without running afoul of obvious objections regarding precursors and continuities. If the scientific revolution allowed the moderns to imagine themselves as engaged in a scientific enterprise that advanced Enlightenment ideals, the shift to the regime of technoscience expresses no less powerfully the demands of an innovative knowledge society.[13]

Quite independently of their epochal significance, there is a need primarily to achieve a better philosophical understanding of the technosciences. So far, the question of the epochal break has been considered entirely subservient to this larger task. However, as Paul Rabinow has pointed out in his comparison of two theorists of technoscience, the very adoption of technoscience as a term of reflection and interpretation has a historical significance that ought to be acknowledged and appreciated. According to Rabinow, Latour's account falls short because he uses the notion of technoscience only to highlight that we finally see how it has always been: the designation 'technoscience' serves to unveil the mythical character of 'science and technology' as if these had ever been distinct and as if the work of purification had ever been a viable enterprise. What was formerly considered science and technology finally comes to fully understand itself under the condition of technoscience. In contrast to Latour, Hans-Jörg Rheinberger appreciates that the acknowledgment and recognition of the technosciences coincides with a transformation and reorientation also of the researchers who use this term as a tool to interpret and understand research activities (Rabinow 1997). The technoscientific regime is no less mythical than was the scientific enterprise, especially if we attribute to it the power to orient a wide variety of research practices, and not just those of nanotechnology: the cosmologist who used to ride high on the wave of prestige accorded to truth-seeking science is now scrambling to show the innovative potential of cosmological research.[14]

According to Rabinow, Rheinberger recognizes that "leading practitioners of the social studies of science, while claiming to be offering a comprehensive understanding of things that escape from the previous metaphysical interpretation of science as epistemologically adequate knowledge, have escaped this metaphysics only by embracing and embodying a technological understanding of being." To embody a technological understanding of being is to become someone other than an

[13] Compare the contributions by Gregor Schiemann and Ann Johnson to this volume.

[14] Inversely, the synthetic chemist who now rides high on the wave of support for nanotechnology, used to show how the discoveries and inventions of chemistry contributed to the larger truth-seeking mission of the scientific enterprise.

adherent of human transcendence through the pursuit of eternal truth. It subsumes all human aspirations and especially those of science under technology, thus (re)discovering Heidegger as a philosopher of technoscience (Rabinow 1997, p. 40f.). This is not the place to articulate the larger philosophical implications of this discovery or of the Heideggerian reframing by Rheinberger, Rabinow, and Forman even of the scientific enterprise within a technological conception of the world. It can be noted, however, that this reframing relates to the epochal break thesis. Even if '(the regime of) technoscience' is an interpretive concept just like 'science' or 'the scientific enterprise,' and even if many of the concrete research questions and practices have remained unchanged, how one thinks about science, technology, and technoscience is not without consequence. How researchers conceive of what they are doing, assigns meaning to their practices and thus orients them, perhaps defines them. By extension this applies to the ways in which philosophers and STS scholars conceive of what researchers are doing – it orients research practice towards certain ideas and goals.

Though physics is still physics and chemistry still chemistry, there is now also nanotechnology and much physics that is "no longer physics."[15] Deprived of their traditional historical mission, all fields of research are oriented towards the regime of technoscience. And though scientific understanding remains a prized good in that regime, there have been changes in what it means to understand something. Philosophers of science and of technoscience may provide different accounts of when the search for understanding starts, how far it goes, and when and why it comes to an end. If the philosophy of science served to idealize and valorize science as a social institution for the critical and public employment of reason, the philosophy of technoscience needs to understand the promise and peril of advancing on the seemingly self-validating path of economic, social, and technical innovation.

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[15] Compare Peter Galison's forthcoming book on recent developments in physics of which many physicists claim that they are no longer physics (string theory, simulation modelling, nanotechnology).

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