SCIENCE TRANSFORMED?

Science Transformed?

DEBATING CLAIMS OF AN EPOCHAL BREAK

EDITED BY
Alfred Nordmann, Hans Radder, and Gregor Schiemann

UNIVERSITY OF PITTSBURGH PRESS

Published by the University of Pittsburgh Press, Pittsburgh, Pa., 15260

Manufactured in the United States of America
Printed on acid-free paper
10 9 8 7 6 5 4 3 2 1

CONTENTS

3

We Are Not Witnesses to a New Scientific Revolution

GREGOR SCHIEMANN

Do the changes that have taken place in the structures and methods of the production of scientific knowledge and in our understanding of science over the past fifty years justify speaking of an epochal break in the development of science? Some philosophical and sociological descriptions of these changes do indeed assert that such an epochal break is becoming apparent (see Forman 2007; Funtowicz and Ravetz 1993 and 2001; Gibbons et al. 1994; Nowotny, Scott, and Gibbons 2001 and 2003; Ziman 2000; and others). In general, this thesis is formulated in such a way as to compare the extent of the changes that have occurred or that are to be expected to the early modern scientific revolution. The point of departure for the current epochal break is presented as a tradition that persisted from the beginnings of the early modern era until about fifty years ago, and from which recent developments constitute a fundamental departure. With the completion of this transformation, science supposedly will have freed itself from its early modern origins and undergone a second scientific revolution.

I, however, do not concur with this thesis of an epochal break in the development of science (hereafter referred to as "the epochal break thesis" for short). The critical appraisal that I offer has three parts.

1. The Extent of the Current Process of Transformation

I acknowledge that there is a serious basis to the epochal break thesis. It rests upon verifiable and to some extent profound changes in the production of scientific knowledge and in our understanding of science that have been occurring globally, but especially in the industrially more developed countries in recent years. Some of these transformative processes have been the subject of intensive academic discussion and public debate in the past several years. To name just a few focal points of the changes at issue: the scientification of more and more areas of society, the accelerated increase in the prominence of technology and economics within science, the growth in the complexity of scientific objects, and the dissolution of disciplinary structures in certain innovative fields of research. Although some of these changes are of a gradual nature, others are indeed drastic. On the whole, there are enough phenomena to point to for it to appear justified to speak of an epochal change in the development of science.

Of course, this viewpoint presupposes that such changes (or breaks, if they are discontinuous) are possible in the first place, and also that they are observable at the time when they are occurring. As for the first of these presuppositions, I demonstrate in the following section that the transition from medieval to early modern science can be interpreted as an epochal change. However, it is questionable whether the participants in such an epochal process of upheaval can themselves recognize the significance of this process, since they lack the necessary distance to perceive the overall context in which it is occurring. This objection cannot be wholly rebutted. Although we can assume fictional standpoints external to the contemporary world, we always remain involved in the events of our own time. Nevertheless, given that we are creatures that must construct our own histories, we have no alternative. We are compelled to compare the contemporary world with past eras to gain the historical orientation that is indispensable for shaping the present in a reasonable way.

But that is just the beginning of the real difficulties involved in the evaluation of the historical dimension of the present development of science. What are the "verifiable" alterations in the production of scientific knowledge? How can an "understanding of science" be pinpointed? What role can philosophy of science play in this? Is it possible to speak of "science" in the singular? To answer questions such as these, it is necessary to set up suitable criteria and to conduct the right kind of inquiries, and that is what I work toward in this chapter. Some of the criteria refer to historical material, and others to philosophical and sociological analyses of contemporary science.

2. Toward a Historical Location of Science's Departure from the Early Modern Era

The second part of my critique deals with the ahistorical character of the epochal break thesis. It is not plausible to present science as having constituted mainly one type (e.g., mode-1, normal science, academic science, modern science) from the beginnings of the early modern era until about fifty years ago, and then to contrast it with a supposedly new type (e.g., mode-2, postnormal science, postacademic science, postmodern science). In describing the period from the beginnings of the early modern era until the present, it is more appropriate to apply a two-phase model that incorporates criteria according to which it is possible to recognize a shift in the history of science during the course of the nineteenth century.

I begin by using a variant of the epochal break thesis to demonstrate that the postulated break is in fact understood as a departure from the early modern era. Then I weigh the merits of the two-phase model as an alternative. Finally, I use it to critique the criteria set forth on behalf of the epochal break thesis.

2.1. A Variant of the Epochal Break Thesis

The variant I discuss—namely, the shift from mode-1 to mode 2-science described by Michael Gibbons and his coauthors—is probably the most well-known formulation of the thesis (Gibbons et al. 1994; Nowotny, Scott, and Gibbons 2001; and 2003). They decisively classify science in the early modern era as mode-1 (Gibbons et al. 1994, 167). The characterization of mode-1 science—aka the "Newtonian model of science"—proceeds by means of five points of contrast with the currently emerging mode-2 (Gibbons et al. 1994, vii, 3, 10).

Mode-2 science, according to the thesis, developed out of mode-1 science only after the Second World War as a result of the drastic increase in the number of trained scientists and in the technical possibilities for knowledge-production (Gibbons et al. 1994, 10, 17, and 44). Some of the preconditions, such as the development of extra-academic research and the dissolution of traditional validity claims, can be traced back to the end of the nineteenth century (e.g., Gibbons et al. 1994, 22; Nowotny, Scott, and Gibbons 2001, 197). Today, mode-2 constitutes a distinct form of knowledge-production that is "different from mode 1 . . . in nearly every respect" (Gibbons et al. 1994, vii) and that interacts with mode-1 (Gibbons et al. 1994, 14 and 9). In the future, however, mode-1 will be "incorporated within the larger system" of mode-2 (Gibbons et al. 1994, 154). Not until then will the revolutionary break be completed.

2.2. A Two-Phase Model of Early Modern and Modern Science

The model that I would like to juxtapose to the epochal break thesis characterizes its caesura in the nineteenth century as only a partial departure from the early modern origins of science. A partial transformation might also have an epochal character. To some extent, the model follows along the lines of other inquiries (e.g., Bachelard 1938; Diemer 1968; Foucault 1970; Lepenies 1976; and Schnädelbach 1983).

2.2.1. The Early Modern Phase

The first ("early modern") phase is characterized by its distinctness from medieval science. In contrast to medieval science, science in the early modern era distinguished between Christian belief and knowledge, introduced the autonomous person as subject of science, disposed of the ancient conceptual distinction between nature and technology, developed experimentation as a method for attaining scientific knowledge, and discovered the technical applicability of scientific knowledge—to name just a few of the significant accomplishments of science in the early modern phase. In sum, the shift from medieval to early modern science can be characterized as an epochal change (in my view it was not discontinuous). Any assertion of a present or future epochal change must be measured against this caesura in the development of science.

The epochal change that initiated early modern science occurred primarily within the natural sciences, which subsequently rose to become paradigmatic for science in general. But the new conceptions of science arising here came to be applied only partially in other disciplines. On the other hand, the natural sciences continued to be reliant upon traditional and necessary criteria of scientificality that were valid for other disciplines. The decisive conception that was taken over from medieval science was the "classical conception of science," which can be traced back to the ancient origins of science. On the classical conception, scientific knowledge must be marked by generality (in concepts and judgments), necessity (of systematic connectedness), and truth (Schnädelbach 1983, 106). The concept of truth took on a key role in this conception. It designated a content on the basis of which the essence of an entity could be determined exclusively, and aimed at a general and solely valid system of knowledge that comprehended the entire world. The classical conception of science was and remains effective as an ideal within the sciences and in their public presentation. This can be demonstrated not only historically, but also with reference to current debates about the conceptions of science. That the epochal break thesis distances itself from the early modern understanding of science is especially clear when one looks at the criticism it makes of the classical conception: current and future science supposedly should be marked not by generality but by particularity, and not by truth but by uncertainty (Nowotny, Scott, and Gibbons 2001, 4–5, 33–37).

Thus, although the modern scientific revolution affected the entire system of the sciences, it was in a twofold sense only a partial change: it left some central features untouched, and it was initially limited to just one area of science. The restricted character of the change corresponds to its only partially discontinuous progress. The notion that the transition from medieval to modern science marked an "epochal threshold" (Blumenberg 1985) is widely contests among historians.

2.2.2. The Modern Phase

In its criticism of the classical understanding of science, the epochal break thesis refers back to the nineteenth century, at which point the classical conception began to collapse and thereby to usher in the second ("modern") phase. Modern science began to distinguish itself from its precursor by impugning the classical claim upon truth, which did not allow for the possibility of revising scientific knowledge. Within the sciences the discussion was led by such researchers as Carl Gustav Jacob Jacobi, Carl Neumann, Bernhard Riemann, and Hermann von Helmholtz. In the case of Helmholtz, a look at the public lectures that were already famous during his lifetime reveals an increasing tendency to do without the notion of truth as a system of knowledge to be attained at some point in the future. The departure from a classical understanding of truth had the consequence of rendering scientific knowledge hypothetical (Schiemann 2009; Heidelberger and Schiemann 2009). The transformation of scientific knowledge claims was taken up within philosophy most prominently by Friedrich Nietzsche. Moreover, the significance of epistemic characteristics that had dominated the understanding of science in the early modern phase was relativized (Lübbe 1986). At the beginning of the twentieth century, quantum mechanics set an example of how the truth of physical knowledge could be irrelevant in a way that had previously not been suspected.

The transformation of science that began in the nineteenth century did not restrict itself to relativizing epistemic criteria. As further characteristics, I would like to mention the incipient entanglement of scientific and societal development, and the crystallization of scientific communities. The technical applicability of scientific knowledge having already been among the central insights of early modern times, the nineteenth century discovered the comprehensive societal utility of the scientific method and of scientific knowledge. The inverse relevance of applied contexts for scientific development took, among other things, the form of increased state sponsorship of the relevant natural-scientific disciplines (including building up their laboratories) and of applied sciences. The production of scientific knowledge thereby came to be tied to its technical application (e.g., the first and second laws of thermodynamics). With the crystallization of scientific communities, the individual as agent of science withdrew to the background.

It is possible to establish connections among the three characteristics of the second phase. I assume that the increasing interconnectedness of science and other societal areas played a sort of key role. It caused the scientific space for pursuing epistemic questions to shrink. At the risk of simplification, one could say that the real insight of the nineteenth century was that science could be highly useful and applicable even without clearing up epistemological questions. Such issues were in a sense put off indefinitely and have since been threatening to fall into oblivion.

2.2.3. The Early Modern and the Modern Phase

One may ask what the relationship is between the two phases and how science at present relates to them. In response, I would say that the second phase takes on some characteristics of the first and that it includes the present. The two phases differ markedly from each other in their appraisal of epistemic questions. With the critique of the classical understanding of science, transepochal criteria of scientificality come to their limit. But if one focuses on the relationship between science and society, the relationship between the two phases appears in a different light. At first glance, then, the second phase may well appear to be just a continuation of the first. In the same sense Martin Carrier, in his chapter in this collection, understands the modern scientific revolution as a technoscientific project. The early modern scientific revolution was already to some extent a result of a close connection between science and societally anchored technology. It already seemed plausible at the time that the technical production and application of scientific knowledge could in the future yield a thoroughgoing improvement of the conditions of life (e.g., Francis Bacon's New Atlantis). Science, however, was practiced primarily by an elite group upon which other societal forces were not really able to exercise any influence. It was not until the nineteenth century, when applications of scientific knowledge took on reality-shaping dimensions, that institutionalized societal forces began to have a lasting impact on the forms of knowledge of production. Although the establishment of mutual, interactive relations between science and society caused the boundary between the two regions to become far more porous, it did not eliminate this boundary altogether. I will return to this issue in section 3.1.

As for the question whether the transformation in the nineteenth century constitutes an epochal transformation, I would like to leave that open. The process does not appear to have reached its conclusion (see section 3.2). As fundamental as some transformations were vis-à-vis the first phase, it is unclear whether they lend themselves to a uniform new characterization or whether it can persuasively be argued that a uniform account is not possible. Current efforts in philosophy and sociology of science to describe the scientific developments that are presently under way (the epochal break thesis being among them) can be regarded as efforts to conceptualize and sum up the second phase in a uniform manner. The absence of a uniform account could be taken to reveal that the process of transformation that began in the nineteenth century has not yet come to a conclusion (see section 3.2). That a process proceeds gradually over a long period of time need not undermine its status as an epochal change (see section 2.2.1). But there are also contrary tendencies that point to a renaissance of classical conceptions—for example, positivism, which aimed to limit scientific knowledge to observable phenomena; pragmatism, which derived claims to truth from the success of scientific theories; and realism, according to which scientific knowledge gradually approaches truth.

2.3. A Critique of the Criteria Offered by the Epochal Break Thesis

In my view the criteria introduced by advocates of the epochal break thesis are insufficient to establish their overall interpretation. They tend either to go back to the early modern scientific revolution or to subsequent developments before the past half-century, or else not be typical of contemporary science as a whole. I confine my criticism here to discussing two examples of criteria that are cited in defense of the epochal break thesis: one that has been proposed by Gibbons et al. (1994), Nowotny, Scott, and Gibbons (2001 and 2003), and another proposed by Alfred Nordmann (2007).

2.3.1. Context of Application

This context comprises "problem-solving and the generation of knowledge organized around a particular application[, and not] merely applied research or development. [It i]ncludes the milieu of interests, institutions and practices which impinge upon a problem to be solved" (Gibbons et al. 1994, 167). I would like to distinguish two primary meanings that are both compatible with these stipulations:

1. The practical-technical context, which is determined by society's expectations and is predicated on the development of specific scientific knowledge and its application. This context was already present in the nineteenth century, when the dynamics of the natural and technical sciences began to become entangled with the transformation of society (see section 2.2.2). In their explication of the concept of a context of application, the authors themselves refer to the establishment of the technical disciplines in the nineteenth century (Gibbons et al. 1994, 4). But these disciplines were supposedly either denied scientific status, or else they completed a transition into nonapplied mode-1 academic sciences (Gibbons et al. 1994, 4). I have two objections to this. The technical disciplines were only temporarily denied scientific status, and only formally—namely, in the refusal to allow doctoral titles to be granted in technical sciences. It is true that there were efforts within the traditional academic disciplines to formulate a conception of science that was divorced from applications, and to use this conception also for the developing technical disciplines. But this phenomenon appeared only as a reaction to the more significant and undeniable increase in the relevance of application also for the traditional academic production of knowledge.
2. The context was already shaped by scientific applications (in the first sense), as discussed by Silvio Funtowicz and Jerry Ravetz (1993 and 2001). In this context problems arise that are characterized by a high degree of complexity, by our only partial theoretical grasp of them, and by controversy about knowledge-related evaluations. Their solution is of urgent necessity for society and is connected with high stakes (Funtowicz and Ravetz 1993, 86; and Funtowicz and Ravetz 2001, 19). Funtowicz and Ravetz mention the problem of the environment as a paradigmatic example, to which Nowotny, Scott, and Gibbons also attribute a key role with respect to the societal conditions under which mode-2 science is developing (Nowotny, Scott, and Gibbons 2001, 6–8).

I assume that the context of application in this second sense is limited to specific problems that are decidedly atypical of the majority of objects of scientific inquiry. Nowotny, Scott, and Gibbons assert that the specific problems in this context of application can only be adequately treated with the elements of knowledge production present in mode-2 (e.g., the "strong contextualization"). It is revealing, though, that the authors themselves concede that they do not think that these elements have or will take on a decisive function for the entire system of the sciences (see Nowotny, Scott, and Gibbons 2001, 131–42).

2.3.2. The Indistinguishability of Nature and Technology

One of the features that Nordmann (2007, 11) points out in characterizing the new type of science that is currently developing, and which is turning away from the modern "project of science," is the "impossibility to separate out the theoretical representation of nature and the technical intervention into nature." That would, according to Nordmann, be the end of the distinguishability between nature, which is the object of theoretical inquiry, and technology, which is mediated by practice. In order to grasp the scope of this claim, I believe it is necessary to make a distinction between two concepts of technology and two corresponding concepts of nature. The early modern scientific revolution devalued the Aristotelian opposition of nature and technology. Instead of having to disregard human actions, science has since then been able to avail itself of technical constructs. But that does not so much eliminate the distinction between nature and technology as invest it with a new meaning. Technology can, for example, be identified as that which can be traced back to human agency. As I have shown in the case of nanotechnology (Schiemann 2005a), it is often possible to pick out parts of technoscientific objects that are not produced by the actions of technicians. It is true that there are an increasing number of objects for which it is impossible or problematic to distinguish between nature and technology. But we are a long way off from a situation where we would only be able to make such a distinction in exceptional cases.

As an example to illustrate the indistinguishability of nature and technology, Nordmann refers to the so-called OncoMouse, a mouse that is genetically modified such that its susceptibility to breast cancer is significantly increased (Haraway 1997). He describes the "technical production of the mouse" as a "stage on which a purely natural phenomenon shows [not] itself" (Nordmann 2007, 13). Even if the process that does not go back to human agency could be identified, it could no longer be characterized as a phenomenon. If this example really did illustrate a general state of affairs, we would be confronted with a world that is ever more technically reshaped—or, as Werner Heisenberg (1953, 412) put it, "confronted only with ourselves." But I do not think that Nordmann's characterization applies even to the OncoMouse example. Even nonprofessional observers can recognize this mouse as an organism that has been seriously damaged by humans, but that does not owe its existence to human agency. One can assume that the damages have consequences for the entire organism and affect all the vital processes of the animal. But this is simply an expression of the animal's natural holistic constitution, which would be also modified by natural injuries. In short, nature remains present even in high-tech laboratories. Indeed, it arises in the form of this mouse's suffering in such a way that it provokes our pity and is thereby part of the motivation to protest against this case of genetic modification.

3. Two Limits on the Current Process of Transformation

The last part my critical appraisal concerns two limits on the current process of transformation of science and also on the descriptions of this process. These remarks are of a more general and more speculative character.

3.1. Science and Society

The epochal break thesis attributes to science's successes an inordinate societal and cultural significance. It is indeed correct to say that science's increasing ubiquity is extending into ever more societal sectors, and also that society is in possession of better means to influence science since scientific knowledge is more widely available (Nowotny, Scott, and Gibbons 2001, 215–29). But the authors who emphasize this point overlook the more astounding phenomenon in this context: despite the scientific permeation of society, societal domains retain their obstinacy, and science is thus still confronted with nonscientific knowledge.

There are various reasons for the resulting preservation of the boundary between science and society. On the one hand, science is far from having lost its specificity. Scientific education and research take place predominately within special institutions. It generally involves concentrating for years on a specific area of inquiry, whereby one attains a competency that cannot even be matched by members of other disciplines, let alone by outsiders who do not have an academic education. On the other hand, I would also like to refer to the loss of cultural significance that, as I mentioned earlier, scientific claims to knowledge have suffered since the nineteenth century. The everyday habits and patterns to which people look for orientation are well able to retain their identity, because they are hardly about to be overthrown by innovative scientific knowledge (as they were by Darwin's theory in the nineteenth century or by modern physics at the beginning of the twentieth century).

Moreover, the black-box character of objects produced by scientific technology plays an important role in maintaining the distant character of science in everyday life (in German, *Lebenswelt*; for more on this concept, see Schiemann 2005b, 89–125). Nowadays, such devices are almost exclusively constructed in a way that one can use them without knowing anything about the way in which they function. Besides, they are designed such that their internal functioning can hardly be damaged even by misusing them. In everyday life we are usually confronted only with the surfaces of modern technological objects. Although ever more aspects of life are directly dependent on the use of scientific technology, and this dependency is increasingly changing our understanding of ourselves, the black-box character of this technology constrains its influence within certain boundaries. There is as little need to take an interest in the scientific knowledge at the basis of a technical device as there is to understand the technical workings of the device.

3.2. The Future of Science

The transformations of science subsequent to the early modern phase need not reflect an irreversible departure from tradition in every respect. They could also constitute a development that takes place within an already existing framework and that even might reveal elements typical of earlier phases of science. So, although science ceased to be primarily epistemically oriented, it might in the future once again become so—especially if we do not regard the transformation in the nineteenth century as an epochal change.

Since society discovered the usefulness of science, science has learned to deploy its world-shaping potential. Nevertheless, there has been increasing pressure on science to develop new methods and new knowledge that do justice to societal needs and demands. Science could still possess an epistemic interest divorced from applications, but may not yet incorporate the requisite measure of routine to satisfy societal requests without suppressing this interest. In the future it could be possible for science to avoid being limited to its utility if its role in applied contexts were to take on a more self-evident character. Furthermore, it is imaginable that societal needs and demands upon applications of science could reach a saturation point. Society, then, could again begin to place a greater value on epistemic issues.

REFERENCES

Bachelard, Gaston. 1938. *La formation de l'esprit scientifique: Contribution à une psychanalyse de la connaissance objective*. Paris: Vrin.

Blumenberg, Hans. 1985. *The Legitimacy of the Modern Age*. Cambridge: MIT Press.

Diemer, Alwin. 1968. "Die Begründung des Wissenschaftscharakters der Wissenschaft im 19. Jahrhundert—Die Wissenschaftstheorie zwischen klassischer und moderner Wissenschaftskonzeption." In *Beiträge zur Entwicklung der Wissenschaftstheorie im 19. Jahrhundert*, edited by Alwin Diemer, 3–62. Meisenheim am Glan, Germany: Hain.

Forman, Paul. 2007. "The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology." *History and Technology* 23: 1–152.
Foucault, Michel. 1970. *The Order of Things: An Archaeology of the Human Sciences*. New York: Pantheon Books.
Funtowicz, Silvio O., and Jerry R. Ravetz. 1993. "The Emergence of Post-Normal Science." In *Science, Politics, and Morality: Scientific Uncertainty and Decision Making,* edited by Rene von Schomberg, 85–123. Dordrecht: Kluwer.
———. 2001. "Post-Normal Science: Science and Governance under Conditions of Complexity." In *Interdisciplinarity in Technology Assessment: Implementation and Its Chances and Limits,* edited by Michael Decker, 15–24. Berlin: Springer.
Gibbons, Michael, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, and Martin Trow. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Sciences*. London: Sage.
Haraway, Donna. 1997. *Modest_Witness@Second_Millennium, FemaleMan Meets OncoMouse: Feminism and Technoscience*. New York: Routledge.
Heidelberger, Michael, and Gregor Schiemann, eds. 2009. *The Significance of the Hypothetical in the Natural Sciences*. New York: de Gruyter.
Heisenberg, Werner. 1953. "Das Naturbild der heutigen Physik." In *Gesammelte Werke,* edited by Werner Heisenberg, 398–420. Vol. C I, *Physik und Erkenntnis: 1927–1955*. Munich: Piper.
Lepenies, Wolf. 1976. *Das Ende der Naturgeschichte: Wandel kultureller Selbstverständlichkeiten*. Frankfurt am Main: Suhrkamp
Lübbe, Hermann. 1986. *Religion nach der Aufklärung*. Graz: Fink.
Nordmann, Alfred. 2007. "A New Mode of Research: Arguing for an Age of Technoscience." Manuscript.
Nowotny, Helga, Peter Scott, and Michael Gibbons. 2001. *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Cambridge, Mass.: Polity.
———. 2003. "Introduction: Mode 2 Revisited: The New Production of Knowledge." *Minerva* (special issue edited by R. MacLeod) 41: 179–94.
Schiemann, Gregor. 2005a. "Nanotechnology and Nature: On the Criteria of Their Relationship." *Hyle—International Journal for Philosophy of Chemistry* (special issue "Nanotech Challenges") 11: 77–96. Available online at http://www.hyle.org/journal/issues/11-1/schiemann.htm.
———. 2005b. *Natur, Technik, Geist: Kontexte der Natur nach Aristoteles und Descartes in lebensweltlicher und subjektiver Erfahrung*. New York: de Gruyter.
———. 2009. *Herman von Helmholtz's Mechanism: The Loss of Certainty. A Study on the Transition from Classical to Modern Philosophy of Nature*. Dordrecht: Springer.
Schnädelbach, Herbert. 1983. *Philosophie in Deutschland, 1831–1933*. Frankfurt am Main: Suhrkamp.
Ziman, John. 2000. *Real Science: What It Is, and What It Means*. Cambridge: Cambridge University Press.