# Gaston Bachelard and the Notion of "Phenomenotechnique"

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# Gaston Bachelard and the Notion of "Phenomenotechnique"

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*The paper aims at an analysis of the oeuvre of the French historian of science and epistemologist Gaston Bachelard (1884–1962). Bachelard was the founder of a tradition of French thinking about science that extended from Jean Cavaillès over Georges Canguilhem to Michel Foucault. In the past, he has become best known and criticized for his postulation of an epistemological rupture between everyday experience and scientific experience. In my analysis, I emphasize another aspect of the work of Bachelard. It is the way he conceptualizes the relation between scientific thinking and technology in modern science. Within this framework, the notion of "phenomenotechnique" is of crucial importance. It is one of the organizing concepts of Bachelard's historical epistemology, and it serves as the organizing center of this paper.*

## 1. Introduction

As David Hyder has suggested in his recent essay "Foucault, Cavaillès, and Husserl on the Historical Epistemology of the Sciences" (Hyder 2003), we can distinguish two lines of French concern within the history and philosophy of science in the middle of the twentieth century. Both are critically engaged with a reception of Edmund Husserl's phenomenology. One of them, the subjectivist side, stands in the tradition of a philosophy of consciousness and is represented by the phenomenology of Maurice Merleau-Ponty among others; the other, the conceptualist side, is represented by a genealogy of epistemologists and historians of knowledge ranging from Gaston Bachelard and Jean Cavaillès to Georges Canguilhem to Michel Foucault. It is with the founder of the latter tradition that this paper is concerned. The paper has the rather restricted goal of looking

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in some detail at Gaston Bachelard's (1884–1962) notion of "phenomenotechnique" as one of the organizing concepts of his historical epistemology.[1] So far, this aspect of Bachelard's work has received comparatively little attention.[2] It is particularly intriguing to note that the ideas of the French philosopher and historian of science appear to have played no role when proponents of the notion of "technoscience" such as Bruno Latour developed their social constructivist and post-constructivist agendas of looking at science in action.[3] They instead polemicized against another characteristic feature of Bachelard's epistemological writings, which had dominated their reception, particularly in France, in the period between the 1960s and 1970s. The issue at stake was Bachelard's postulate of an epistemological rupture between pre-scientific thinking entrenched in the immediacy of unquestioned everyday life, and scientific thought, which needed the confines of a scientific culture to progress.[4] This dichotomy was understood to go against the grain of a symmetric assessment of scientific activity which refused the distinction between true and false its organizing power in structuring narratives on science.

It is obvious that there is an intriguing element of faith and belief in "scientific progress" in Bachelard, his writings at times even "bubbling over" with his enthusiasm for science, as Mary Tiles once remarked (Tiles 1984, p. 4). On the occasion of the International Congress of Philosophy of Science in Paris in 1949, he even went so far as to claim that "it appears that the very *existence* of science is defined as a *progress* of knowledge" (Bachelard [1951] 1972b, p. 36). However, "progress" in Bachelard's sense, as we shall see, means permanent goings-on, a continuous movement of differential reproduction rather than a movement toward a preconceived end, or an approximation of an "ultimate reality" (Bachelard [1928] 1987).

In a recent book, Cristina Chimisso has argued that many features of Bachelard's work can be understood better if one recognizes that he was deeply embedded in the French education system of the early twentieth century with its idea of "scientific spirit," and if one recalls his own long practice as a school teacher of physics and chemistry at the *Collège* of his home town Bar-sur-Aube (Chimisso 2001, especially Chapter 3). We must also not forget, as Jean Gayon reminds us, that Bachelard, before choosing to teach, had considered becoming an engineer (Gayon 1995, pp. 3–11). This may help us to understand that his epistemology has two irreducible

1. The term is Dominique Lecourt's. See Lecourt 2002, introduction.

2. Notable exceptions are Gaukroger 1976; Castelao-Lawless 1995; and particularly Gayon 1995.

3. See particularly Latour 1993.

4. Examples of this trend are the writings of Louis Althusser and Etienne Balibar.

dimensions. From the perspective of the *scientist as a person,* it takes the form of a psychology or even a psychoanalysis of the scientific spirit; from the perspective of the *scientific process,* it takes the shape of a praxeology of scientific work. In this paper, I would like to address those aspects of his conception of the contemporary sciences that appear to me to contain key elements for understanding their peculiar dynamics. Much of the argument revolves around Bachelard's conception of what it means to be a scientific object in the sense of a technophenomenon.[5]

## 2. Premises

Although the cluster of epistemological books that Bachelard wrote between 1949 and 1952 may be said to represent a radicalization of his thoughts about the relation between science and technology (Dagognet 2003), there is also a remarkable thematic continuity to be observed with the first series of epistemological works in the late 1920s and the 1930s (Gayon 2003). At the center of this continuity stands the notion of "phenomenotechnique." Gayon has claimed that "Bachelard tried to circumscribe the precise nature of the technical aspect of science. The first part of this enterprise consisted of the elaboration of the concept of 'phenomenotechnique.' This concept is without a doubt the essential piece of the philosophy of applied rationalism" (Gayon 1995, p. 39). In a similar vein, Teresa Castelao concludes: "Phenomenotechnique is one of the most potentially rich concepts that Bachelard has to offer to contemporary philosophy of science and to science studies in general" (Castelao-Lawless 1995, p. 45). The concept aims at conceiving of technology not as an eventual byproduct of scientific activity, as a derivative product through which science manifests itself in society, but as constitutive of the contemporary scientific modus operandi itself. Insofar as the technological mode of action is engaged in the core of the scientific enterprise, the technological object itself acquires an epistemic function. In a paper on microphysics from 1931, Bachelard expresses himself as follows: "We could therefore say that mathematical physics corresponds to a noumenology quite different from the phenomenography to which scientific empiricism confines itself. This noumenology implies a phenomenotechnique by which new phenomena are not simply found, but invented, that is, thoroughly constructed" (Bachelard [1931–32] 1970, pp. 18–19).

For the purposes of the present essay, we can take Bachelard's notion of "noumenon" to be roughly equivalent to the ordinary notion of concept or scientific law, provided we respect Gayon's caveat that it has to be taken

5. For a valuable collection of texts addressing the major epistemological concerns of Bachelard see Bachelard (1971) 2001.

neither as an arbitrary hypothesis nor an immutable essence, but rather as an entity in flux, a sort of "progress of thought" (Gayon 1995, p. 43). In invoking the example of the separation of isotopes in mass spectrometers, Bachelard comes back to this point almost twenty years later, concluding that the scientific activity of our age consists in the "noumenal preparation of technically constituted phenomena. The trajectories along which the isotopes in the mass spectrometer are separated do not *exist* in nature; they have to be technically produced" (Bachelard [1949] 1998, p. 103). What tends to be perceived as a fact, as something given in the real world, has to be seen as a result of and even derives its existence from a circuit that is at the same time material and discursive. Technophenomena are theoretically invested entities. The philosopher of science must try to analyze this investment in order to understand the enormous productivity of contemporary science and technology. This material-discursive circuit is dialectically constituted. It has no clearly definable starting point on either the noumenal or the phenomenal side. Its thorough philosophical understanding is as far away from empiricism as it is from rationalism. One can only assess it by immersing oneself in the particulars of the phenomenotechnical work of the sciences. Bachelard's technical phenomenology can be seen as an answer to Husserl's phenomenology, which remained firmly entrenched in the life-world. But whereas Husserl wanted to save Western scientific rationalism by reconnecting the sciences, at least potentially, to everyday experience, Bachelard contended that the sciences themselves were to be assessed as particular, concrete forms of life.

The decisive philosophical challenge was for Bachelard less a radical constructivist stance, as might perhaps be guessed from the above quotations. His conclusion pointed in another, rather surprising direction. He contended that with the ever tighter interplay between ever more specific forms of knowledge and the phenomenal world, the sciences necessarily became fragmented into different epistemological regions. He postulated that their conceptual dynamics finally became inseparable from the phenomena in which and through which they expressed themselves. Therefore, so it appeared to Bachelard, in order for the sciences to be understood properly, they had to be studied in exactly these regional manifestations and in all the details of their diverse technical realizations. In order to do this, he tried to situate himself beyond the received brands of philosophy of science: beyond positivism and formalism, empiricism and conventionalism, realism and idealism, positions that he judged to be the results of impermissible abstractions that did not do justice to the complexity of the contemporary sciences. He did not want to side with any of these philosophical traditions. In order to express the dialectical tension in his own

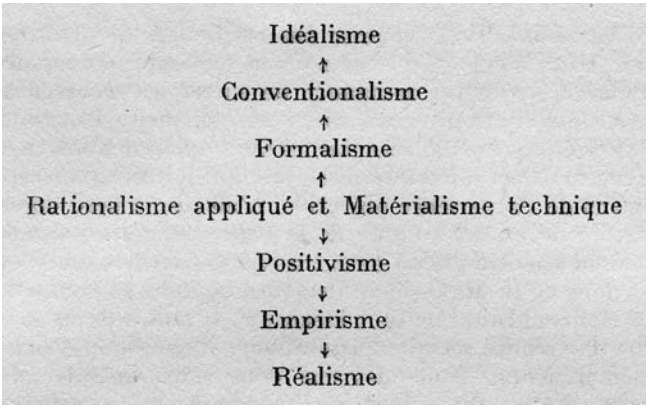


**Figure 1.** Taken from Gaston Bachelard, Le rationalisme appliqué. Presses Universitaires de France, Paris 1949, 3rd edition, Quadrige/PUF, Paris 1998, p. 5.

approach, he called it "applied rationalism" or "technical materialism" (see Figure 1, Bachelard [1949] 1998, p. 5).

Consequently, in his *Philosophy of No* in 1940 Bachelard called for a "dispersed" or "distributed philosophy," a philosophical position that thus did not shy away from engaging with the diverse sciences in the process of their becoming. He pleaded for a philosophy that would be able to account for the vastly different types of theory involved in the multiple and various activities of the sciences, for the wide range of their reifications, and particularly for the multifarious procedures of discovery (Bachelard 1940, p. 10). He even went so far as to postulate that each interesting problem, each experiment, or even each equation required a philosophical reflection of its own. According to Gayon, "Bachelard the epistemologist has over and over again renewed his adhesion to a rationality of detail that pluralizes the object at the very same time it rectifies and realizes it" (Gayon 1995, p. 4). Bachelard was convinced that it was not the task of epistemology to spell out general, timeless norms for scientific knowledge acquisition. According to him, it was not the epistemologists, but the scientists alone who had the right to define the continuously shifting boundaries of their trade. Consequently, he summarized his program by rhetorically asking the scientists to make available their daily laboratory experience, the daily dramas of their daily work, to the philosophers of science, so that they could reflect properly about the practice of contempo-

rary science: "Tell us what you think, not when you quit the laboratory, but during the hours when you leave ordinary life behind you and enter scientific life. Instead of leaving us with your empiricism of the evening, show us your vigorous rationalism of the morning" (Bachelard 1940, p. 11).

If the dynamics of the process of knowledge acquisition depended on regionalization, a plurality of methods had to be acknowledged as well as an inherent openness toward the process as such. We could speak of a process epistemology in this respect, an epistemology of emergence and of innovation, a "philosophy at work" (Bachelard [1949] 1998, p. 9). For Bachelard, it was essential for philosophers of science to keep in touch with the development of the sciences. Epistemology had to be understood as a permanent reflection of that development. Following this line, Bachelard claims: "We must attempt a rationalism that is concrete and in line with the precision of particular experiments. It is also necessary that our rationalism is sufficiently *open* to receive new determinations from the experiment" (Bachelard [1949] 1998, p. 4).

In short, an epistemology that tries to assess scientific thinking in its dynamicity must be as plastic, as mobile, as fluid, and as risky as scientific thinking itself. Two consequences follow. The first is a regional mobility of epistemology according to the regionalization of knowledge. Modern science creates what Bachelard claims to be "kernels of apodicticity" that can only be assessed from inside, if one is ready to play the game according to the rules of each of the kernels. In this respect, Bachelard often also talks of cantons, regions, or domains of knowledge within the city of science, such as the "relativistic canton" in the "city of mechanics" (Bachelard [1949] 1998, pp. 132–133). These cantons are islands of scientific culture; they create their own cultural codes and forms of emergence, which only an intimate knowledge of the respective region allows one to judge. This means that epistemology must engage itself with the intricacies of these particular islands.

The second consequence is mobility along the historical axis. "Scientific thinking is essentially a rectification of knowledge," claims Bachelard. "It judges its historical past by discarding it. Its structure is the consciousness of its historical errors. Scientifically one thinks of truth as the historical rectification of one long error, one thinks of experience as rectification of a primary and common illusion" (Bachelard [1934] 1968, p. 173). One is tempted here to think of Karl Popper's critical rationalism. But here we also come to the core of what Bachelard tried to capture with his notion of *recurrence.* What is at stake is probably less the epistemological rupture between a scientific mode of thinking and a "primary illusion." Much more important appears to be the fact that within scientific activity itself, a per-

manent process of rectification and reorientation is going on, a process that permanently transforms the truth of today into the error of yesterday. And since the truth of today is constituted through this very movement, it receives from it that strange double character of being an arbiter of the past and at the same time being subjected to the very same ongoing rectification process. Any scientific truth of today may thus itself one day become an error of the past. This is the core of Bachelard's idea of the historicity of science, a historicity that marks it as a peculiar culture of truth. "The spirit has a variable structure from the very moment where knowledge has a history" (Bachelard [1934] 1968, p. 173). Knowledge *is* an evolution of the spirit, it is nothing that is accomplished once and forever, it is grounded in its very own discardability, and not in the timeless unity of a thinking ego. Reason is always cunning reason, for methods are strategies of acquisition with the precarious status of "*risking* themselves in a new acquisition on the basis of being enforced through a former acquisition" (Bachelard [1951] 1972b, p. 39, emphasis added). They modify and at times even consume themselves in their own application.

### 3. Major Aspects of Bachelard's Epistemology

This is the place to have a closer look at a few major aspects that characterize Bachelard's epistemology. One of them involves scientific object, scientific spirit, and objectivity; the other has to do with the social character of science.

#### Scientific Object, Scientific Spirit

Let us first see what consequences Bachelard's version of process epistemology has for the conception of scientific objects and of scientific objectivity. With that, I come to the core of my assessment of Bachelard's phenomenotechnology. Two aspects of the problem can be distinguished. The first, already mentioned at the beginning, is that in general, the objects on which the sciences work—the phenomena they are concerned with—are not immediately given to the senses. For Bachelard, it is built into the very notion of the scientific spirit that its objects are entities that cannot be grasped without mediation, because they are always a product of scientific work. "Scientific objectivity is only possible if one has broken with the immediate object, if one has refused the seduction of the first choice, if one has arrested and contradicted the thoughts that spring from a first observation" (Bachelard 1938, p. 9). On another occasion Bachelard notes that "one must accept a veritable rupture between sensual knowledge and scientific knowledge" (Bachelard [1938] 1969, p. 239). This epistemological rupture, in a kind of originative epistemic gesture, or "epistemological act" (Bachelard 1951, p. 25), constitutes and transforms

a perceived phenomenon into a scientific object. What is achieved in this act is the transformation of something that had been taken as given into a *problem.* A scientific object is a phenomenon that has been drawn into a cycle of rectification; it is not constituted once for ever, but it remains a scientific object only through its being constantly reconstituted and rectified. The epistemological rupture serves to mark the transition from everyday knowledge to the act of scientific thinking, while at the same time it inscribes itself into this very act and thus becomes an intrinsic hallmark of a continued scientific engagement with the world.

The second aspect of Bachelard's conception of the objectivity of science is that not only are its objects mediated, but that the knowing spirit is not immediately given either. Bachelard claims that "the march toward the object itself is not objective from the beginning" (Bachelard [1938] 1969, p. 239). The knowing spirit has to externalize itself and become "instrumental" (Bachelard [1938] 1969, p. 218), that is, its "formation" is itself technically mediated. It must engage in a cycle as well—a cycle of instruction.

As a result, both scientific spirit and scientific object enter in a mutually exteriorizing and at the same time mutually interiorizing relation with each other. This double movement is instantiated and epitomized by scientific instruments. They are embodiments of acquired knowledge and at the same time help to produce the object as a technophenomenon. In contemporary science, Bachelard claims, "the instrument is the necessary intermediary in the study of a definitely instrumented phenomenon that has been designed as an object of a phenomenotechnique" (Bachelard [1949] 1998, pp. 2–3). As a materialized noumenon, the instrument sits in the center of the epistemic ensemble: "In modern science, the instrument is veritably a reified theorem" (Bachelard 1933, p. 140). It is not a passive device positioned between a Cartesian mind and the outward world, destined to enhance the subject's discriminatory capacities. At any given time, the instrument represents the material existence of a body of knowledge. The phenomenon is provoked as a problem at the knowledge horizon and may itself require new concepts in order to be accommodated. Phenomenon and instrument, object and scientific spirit, concept and method are all joined in a process of mutual instruction.

Occasionally, Bachelard speaks of "construction" in this context. "Nothing is given. Everything is constructed" (Bachelard [1938] 1969, p. 14), we read for instance in *The Formation of the Scientific Spirit.* But in general, he prefers the term "realization": "Science *realizes* its objects without ever finding them readymade. Phenomenotechnology *extends* phenomenology. A concept has become scientific according to the proportion to which it has become technical, to which it is accompanied by a technique

of realization" (Bachelard [1938] 1969, p. 61). Whereas the term "construction" stresses the part of the material object, the term "realization" stresses its conceptual counterpart. Most appropriate, however, is the term "instruction," for it insists on the mutuality of the process in which the object itself becomes an agent in an intimate knowledge relation, in an epistemic "engagement" in the words of Bachelard: "The position of the scientific object, actually the object as an instructor, is much more complex, much more *engaged.* It claims a solidarity between method and experience. One must therefore know the *method of knowing* in order to grasp the *object to be known,* that is, in the realm of methodologically valued knowledge, that object which is capable of transforming the method of knowing" (Bachelard [1949] 1998, p. 56). Thus, we are confronted with a deeply non-nativist, non-naturalistic procedure on both sides. The scientific spirit must form itself against nature and against its own inborn inertia. It can become instructed not by self-education, but only by engaging with the objects of the world, by "purify[ing] the natural substances and thus bring[ing] order into nebulous phenomena" (Bachelard [1938] 1969, p. 23). Just as the scientific spirit is not ready-made, the objects of science are neither immediately given nor immediately ready to be grasped. They take shape in a long and tedious historical process of purification and ordering.

In its subjective dimension, Bachelard has described this engagement in what he calls a *psychoanalysis* of scientific knowledge. It is one of the characteristics of his historical epistemology that it does not rely on postulating a certain structure of scientific thought or a particular logic of scientific thinking. In contrast, Bachelard sees it as a deliberately *psychoepistemic* activity. The act of gaining knowledge is an activity in which the person of the scientist is involved as a whole. The process of gaining knowledge is *work.* In the center of its description, amounting to a kind of *"phenomenology of work"* (Bachelard [1931–32] 1970, p. 14) stands what Bachelard calls the "epistemological obstacle." This is not, as he explains right at the beginning of his *Formation of the Scientific Spirit,* some difficulty that may impose itself from outside, such as the sheer complexity of the world for instance, or the physical limitations of our senses. It is rather "in the act of knowing itself that slownesses and troubles appear, intimately, in a kind of functional necessity" (Bachelard [1938] 1969, p. 13). These slownesses and troubles have to be surmounted if the objectivizing process of knowledge acquisition is to work. In it, there can be neither immediacy nor belief: "The real is never 'what one might believe,' it is always only that which one *should* have been thinking. Empirical knowledge is lucid only *after the event,* after the apparatus of reasoning has been set in motion" (Bachelard [1938] 1969, p. 13). Knowledge can be sanctioned in an act of

recurrence, but there is no straightforward procedure that would grant its acquisition. The emergence of knowledge remains in the realm of messy confusion, of trying out, in the inertia of preconceived opinions; it is again and again in need of those "epistemological acts . . . that bring unexpected impulses into the scientific development" (Bachelard 1951, p. 25). In contrast to many of his contemporaries, such as Hans Reichenbach, Bachelard does not exclude this messy space of discovery from the domain of epistemology. He rather declares it as its center.

## Science as a Social Process

It is another distinguishing feature of Bachelard's conception that he also attributes a social or communitarian dimension to this process. Modern knowledge acquisition can no longer be conceived of within the confines of the traditional relation between a solitary subject and its object as stipulated by theories of knowledge in the Cartesian tradition. It is set in motion and carried out as a *collective* enterprise effectively performed by a scientific community and bound together through the "effective interpsychological work" of language and experiment (Bachelard [1949] 1998, p. 55). As mentioned already, it is resumed in regional rationalisms, cantons or quarters within a "scientific city" which Bachelard expressly characterizes as scientific "cultures." A culture, for Bachelard, is defined as "an accession to an emergence" (Bachelard [1949] 1998, p. 133), that is, as a milieu that allows for the appearance of novelty, of unprecedented events. If the artistic act of creating novelty might be more of an individual nature, in the sciences in contrast, Bachelard contends, "these emergences are effectively constituted socially" (ibid., p. 133). Even the epistemological acts of scientific geniuses are, as a rule, firmly embedded in these cultures.

Moreover, we have to distinguish several different aspects of modern scientific cultures. The first one is grounded in the very psychological constitution of an individual versus a group of tightly bound individuals engaged in a common epistemological project. "Man hesitates," says Bachelard. But "the school—in the sciences—does not hesitate. The school—in the sciences—carries along" (Bachelard 1951, p. 6). The school, one could say, is the social expression of the process of recurrence that characterizes scientific knowledge acquisition. It provides the necessary bonds for the "dialectics of attachment and engagement" to play out their role (ibid., p. 12).

Another aspect of modern scientific culture is specialization. The rationality of the modern sciences is cantonized. In contrast to many of his contemporaries who deplored the overspecialization of the sciences, Bachelard sees specialization in its positive aspects as an "actualization of a general-

ity" (ibid., p. 11). "It dynamizes the spirit. It works. It works endlessly," and besides that, "it is the most specialized cultures that are most liable to substitutions" (ibid., pp. 14, 12). On the one hand, they set free the "forces of fixation" that are the counterpart of the disposability of the modern scientific spirit (ibid., p. 13). On the other hand, they instigate and maintain the game of substitution of methods, categories, and phenomena. The more narrowly defined an area, the more readily conventions, measurements, descriptions, and classifications can become altered and subjected to modification, and then eventually also may be carried over into other areas of research. Specialization creates epistemic flexibility. We see here a glimpse of the idea of patchwork productivity of knowledge acquisition. Finally, there is the cooperation between the *theoretical* and the *technical* society in the scientific city. These two societies are engaged in mutual comprehension. It is this "mutual, intimate, and agitating comprehension" that constitutes, to Bachelard, the "really new philosophical fact" of modern science. The convergence of precision and power in localized technophenomenologies is a veritable *social* feat. It is not of the order of a "*natural* necessity." It constitutes the very "*fabric of phenomena*" of the contemporary scientific world (Bachelard 1951, pp. 9–10).

These few remarks may suffice to demonstrate that a social as well as a cultural dimension is irreducibly built into Bachelard's historical epistemology. At this point, we can also see how the dialectics of the technical and the noumenal within the epistemic core of the research process translates and redoubles itself in an intimate relation between science and technology on the societal level. This aspect particularly characterizes the later epistemological work of Bachelard, beginning with *Applied Rationalism* of 1949. But it is also clear that there remains an inescapable tension that Bachelard already recognized in his first book, *Approximate Knowledge,* in 1928. Gayon formulates this Bachelardian tension as follows: "Science constantly faces 'the fundamental irrationality of the given.' Industry, in contrast, materially *realizes* a clearly recognized and pursued rationale. 'On one side, one seeks the rational, on the other, one imposes it.' Technology *plainly realizes its object,* and for that very reason, radically escapes the spontaneous skepticism that is one of the most distinctive cognitive attitudes of scientific thinking" (Gayon 1995, p. 38).[6]

#### 4. Technoscientific Productivity

With this double aspect of the relation between the technical and the scientific, I come back to the central theme of this special issue, technoscientific productivity. As already mentioned, in order to stress the

6. The quotes are from Bachelard 1938a, p. 160.

inextricability of this relation, in his later epistemological work Bachelard uses the compound notions of "applied rationalism" and "technical materialism" for his own position. Materialism here refers to a "reality" "transformed" by rationalism and thus carrying "the mark of rationalism" (Bachelard [1949] 1998, p. 8). It is crucial in this context to explicate Bachelard's concept of rational application in more detail. It operates on a level distinctly different from the well-known and worn distinction between basic science and applied science. In its traditional form, the dichotomy can be formulated as follows. Basic research is carried out in a space in which one is free to play around, to experiment and to hypothesize. Sooner or later, fundamental solutions arrived at in basic science will find their technological applications in society at large. The notion implies that basic science operates in a space that is essentially value-free and becomes socially and ethically laden only in the process of its translation, dissemination, and scaling up: in short, in its industrial application for certain purposes, for good or for bad.

Bachelard however sees the epistemic and the technical in no such linear relation, but in a much more intimate one, in fact in a mutual coevolution that carries the whole burden of modern science's productivity. Application is not extrinsic to modern knowledge, it is not just added to some epistemic core; it exerts its action at the very level of concept formation itself; the technical belongs to the essence of the modern sciences themselves. In *The Formation of the Scientific Spirit,* Bachelard formulates quite expressly: "In order to accommodate new experimental proofs, one must . . . *deform* the primitive concepts. One must not only study the conditions of application of these concepts, but one must incorporate *the conditions of application of a concept into the very meaning of the concept itself*" (Bachelard [1938] 1969, p. 61). Consequently, applicability is built right into the core of modern sciences' concept formation. Stephen Gaukroger has called this the "essence of [Bachelard's] phenomenotechnics" (Gaukroger 1976, p. 221). Applied rationalism is thus technically implemented materialism. It is not the idea of a science in search of application, but of a science that is taken and accepted as science *because* it moves in and has always existed in the realm of the applicable, because its very epistemological constitution has a technical dimension, because application is built into the very meaning of concepts and into the rules of concept formation, because the technical is built into the experimental phenomena, and because, just the other way around and in a symmetrical fashion, the noumena are built into the instruments and take on an instrumental form that further serves to develop the whole phenomenotechnical machinery. Here, too, Bachelard distances himself from describing the situation with terms like "construction" or "artifice": "The factitious," he

contends in a discussion of Hans Vaihinger's fictionalism, may well provide a "metaphor" for the situation, "but it cannot deliver a syntax, like the technical, capable of linking arguments and intuitions" (Bachelard 1933, pp. 141–142). The same holds for utilitarian and pragmatist interpretations of science whose "scattered pluralism" Bachelard deliberately rejects, too, in the name of a "coherent pluralism" (Bachelard 1932).[7] Against any superficial methodological mobility he insists on the indispensable virtues of the claim to truth as the "constant power of integration of modern scientific knowledge" (Bachelard [1951] 1972b, p. 40), thus balancing its productive regionalization, the latter being equally indispensable, for "without the multiplication of perspectives, there is no objectivity" (Gayon 1995, p. 4). It is its networked material entrenchment, mediated by instruments and dispersed throughout society in the form of standardized industrial products, which conveys the necessary minimum of coherence to the sciences in all their diversifications and despite the fact that "the language of science is in a permanent state of semantic revolution" (Bachelard 1953, p. 209). This minimum of coherence is precisely due to the deep structure of application of modern knowledge. "In the new rationalism, the chief notion is that of technique. Modern science is an intrinsically 'technical' science" (Gayon 1995, p. 36).

## 5. Historical Epistemology

These aspects of Bachelard's thought, pertinent as they are for an understanding of technoscientific productivity, have barely found their place in recent science and technology studies. The aim of this piece of exegesis has been to point to this gap rather than to close it. To conclude, I would like to come back to Bachelard's project of a historical epistemology. In fact, the project has two aspects. The first is connected to the problem of technoscientific productivity and the particular slant that Bachelard gives it with his notion of phenomenotechnique. Scientific objects—or technophenomena for that matter—carry an intrinsic history along with them, because experimental work has always already been invested in them, once the immediacy of the common sense grip on whatever was thought to be there has been broken. The history of science possesses a very peculiar connectivity that follows from the lingering path of its auto-rectification. It is essentially open-ended, surpassing and at the same time bent back on itself. In that respect, "the history of the sciences appears as the most irreversible of all histories" (Bachelard 1951, p. 27). Scientific objects are always transformations of earlier scientific objects and thus intrinsically historical entities. So, for instance, "the 'electrical reality' of the nine-

7. He uses the latter term as early as 1932 prominently in a book title.

teenth century is quite different from the 'electrical reality' of the eighteenth century" (Bachelard [1949] 1998, p. 9), and yet they are perceived as transformations of the same range of phenomena. Through the tight coupling of the noumenal and the technical within scientific activity, and of science and technology on the societal level, applied rationalism becomes part and parcel of the material culture of humanity. It is important, however, to recognize that despite this irreversible historicity, there is, according to Bachelard, no historical necessity for the sciences to arise, there is no "historical reason" in the strong Hegelian sense of *Vernunft* at work here (Bachelard 1951, p. 23). The synthetic achievements of the sciences are thoroughly emergent phenomena; their emergence is not programmed in a teleological manner. Bachelard quotes Louis de Broglie as his witness in this context: "Many scientific ideas of today would be different from what they are if the paths followed by the human spirit to approach them would have been different" (de Broglie 1947, p. 9; quoted in Bachelard 1951, p. 21).

The second aspect of Bachelard's project of a historical epistemology is that despite the impossibility, in principle, of anticipating scientific progress, despite the non-existence of a historical reason, the actual state of knowledge cannot but serve as a grid for the evaluation of science past. Historical judgment is a recurrent action that carries a kind of teleology of hindsight along with it; history is illuminated by, and always appears in the light of, a "finality of the present" (Bachelard 1951, p. 26). In the light of this finality, history of science divides itself into a sanctioned part and into one that has been superseded. Since *science itself* makes this distinction, since it *is* in essence a process of self-detachment, of self-distinction, of self-polemics, and of self-negation, the historical epistemologist who wants to be up to date and follow the movement of his objects, will find his own activity falling under the same rules. However, handling these recurrences requires of him a "veritable tact," for they carry a "ruinous element" along with them: "The philosophical position I assume here," Bachelard asserts, "is certainly not only difficult and dangerous. It even contains an element of self-ruin: this ruinous element is the ephemeral character of the modernity of science. If one follows the ideal of the modernist tension I propose for the history of the sciences, it becomes necessary that the history of the sciences be frequently redone, be often reconsidered" (Bachelard [1951] 1972a, pp. 143–144). If the sciences themselves constantly alter their judgment of the past, epistemology is bound to follow them in a process of co-transformation. Historical epistemology itself then becomes a historically changing enterprise. If the culture of the scientist is a "history of permanent reformation" (Bachelard 1951, p. 13), the culture of the epistemologist cannot be different in this respect. While

the historian, in principle, may not be out for judgments, the historical epistemologist must judge. But he also must be ready to change his judgment in the face of new scientific developments.

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