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*Edited by Flavia Padovani and Adam Tamas Tuboly*

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*This volume is dedicated to the memory of Michael Friedman (1947–2025)*

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# 16
# BACHELARDIAN AND CONTINENTAL EPISTEMOLOGIES

*Matteo Vagelli*

## An "unusual style" in French philosophy

The work of Gaston Bachelard is often taken to exemplify French historical epistemology to the point that the latter is sometimes reductively identified with the former.[1] Bachelard teaches chemistry and physics in *lycées* before succeeding Abel Rey in 1940 as professor of history and philosophy of science at the Sorbonne and as director of the *Institut d'histoire des sciences et des techniques* (IHST). His portrayal has contributed to cementing the popular image of the philosopher as an authoritative figure, marked by a distinctive long white beard (see Chimisso 2001: Chapter 1). Georges Canguilhem describes Bachelard's irruptive novelty in the French philosophical scene – thanks to the publication in 1928 of his doctoral thesis, *Essai sur la connaissance approchée* – as a new, "unusual" and "rural style" in philosophy (Canguilhem 1957: 5). The seemingly abrupt and unpolished tenor of this style emerges from a deliberate intransigence, a stance that both enables and preserves the audacity and innovative force characteristic of Bachelard's philosophical enterprise. Indeed, against prevalent continuous epistemologies, historiographies, and views of human reason as uniform, such as those promoted by Émile Meyerson and Pierre Duhem (Chapter 15), Bachelard emphasizes the discontinuous nature of scientific knowledge and the disunity of science and uses general history as a negative counterpoint to define the task of the history of science. The shifts he introduces into the so-called "French style" of epistemology and historiography (Braunstein 2002) have profound implications for the continuation of French historical epistemology and make Bachelard's position stand out both with respect to the prevailing approaches in the French philosophical context of his time and in the larger panorama of so-called "Continental" philosophy of science (e.g. Gutting 2005; see Fabry and Roux 2025).

Although Bachelard belongs to the same generation as the founding members of the Vienna Circle (Chapter 17) and becomes acquainted with their works, a sustained dialogue with the views of the logical empiricists never got off the ground.[2] This partly explains why Bachelard's "heritage" has to a large extent remained "invisible" (Knapp and Bringuier 1972) – especially outside France, where he is sometimes better known for his works of poetry and imagination than for his epistemological writing.[3] The "missed encounter"

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between Bachelardian epistemology and the so-called "Popperian school" (Lecourt 1975: 9; see also Chapter 23) also played a role in this relative neglect. A closer engagement with the novel epistemological elements introduced by Bachelard would have been beneficial to the unfolding of Anglophone discussions around the philosophy of scientific experiment, a pluralist philosophy of science, and the historiography of science. In this chapter, I will provide an overview of each of these three aspects of Bachelard's reflection.

## Singing electrons

Educated within the framework of Newtonian physics, Bachelard completed his studies during the period of rapid scientific advancement characterizing the first decades of the 20th century, which prompts Bachelard to acknowledge the emergence of a "new scientific spirit". Indeed, the development of subatomic physics constituted a shift from an ontology of substances to one premised in relations, as the primacy of visible gave way to the invisible, and the immutable and eternal gave way to mutability. The "sur-objects" introduced by microphysics were thus non-substantial, relational, and technical entities (Bachelard 1931, 1949: 139). Furthermore, the newly emerging contemporary science did not limit itself to describing phenomena but rather constituted a "phénoménotechnique" actively producing them. This new form of science ushered in not only novel scientific theories but also corresponding changes in epistemology and the history of science.

The notion of *phénoménotechnique* – that is, the technical-instrumental production of scientific concepts – is the centerpiece of Bachelard's philosophy of experimentation. Bachelard first uses the term in 1931–1932, in the article "Noumène et microphysique", to characterize the effort of mathematically constructing a noumenological reality. In this context, the Kantian noumenon becomes a mathematical structure that underlies phenomena. With the concept of *phénoménotechnique*, Bachelard contrasts the simple description of phenomena with the epistemological consideration of their experimental production. It becomes thus clear that the neologism is a pun on Husserl's idea of phenomenology as a description of conscious experience (see Chimisso 2009). In this sense, Bachelard argues, "contemporary atomic science is more than a description of phenomena, it is a production of phenomena" (Bachelard 1931: 24; unless otherwise indicated, translations are mine). The concept also appears in Bachelard's first major work, *Le nouvel esprit scientifique*, where he highlights "the polemical character of knowledge" by shedding light on how scientific phenomena "must be selected, filtered, purified, shaped by instruments; indeed, it may well be the instruments that produce the phenomena in the first place" (Bachelard 1934/1984: 12).

From its early occurrences, the concept of *phénoménotechnique* is intricately linked to the effort of synthetically structuring reality through mathematics:

> We could thus say that Mathematical Physics corresponds to a noumenology that is quite different from the phenomenography to which scientific empiricism claims to be confined. This noumenology illuminates a *phénoménotechnique* by which new phenomena are not simply discovered but invented, constructed entirely from scratch.
> *(Bachelard 1931: 18–19; see also Bachelard 2021)*

Shortly thereafter, Bachelard emphasizes the application of the notion of *phénoménotechnique* to the technical and experimental production of science. The guiding idea in

this context is that technology and technical realization are the true keys to objectivity (Castelão-Lawless 1995: 51). Bachelard highlights the laboratory as the place where theoretical thought is gradually realized, and the involvement of instrumental processes in the "solidification of causality" as the primary method of this realization (Bachelard 1936/2000: 77). Bachelard's increasing interest lies in the production of particles by experimental physics – in his view, "electron, proton, positron, neutron" are all seen as "products of electrical techniques" (Bachelard 1951: 91).

As has been noted, Bachelard's notion of *phénoménotechnique* was also taken up in the so-called "practical turn" animating Anglophone philosophy of science since the late 1970s (e.g. Gaukroger 1976; Castelão-Lawless 1995; Rheinberger 2005). Surprisingly enough, the rediscovery of Bachelard's idea that physical particles are fabricated rather than discovered received both constructivist (Latour and Woolgar 1979) and realist developments (Hacking 1983, 1984/2002).[4] These latter, while insisting on the "creation of phenomena" by contemporary physics, also hinged around Bachelard's distinction between existence and "phenomenological realization":

> The electron existed before the 20th century men and women. But before them, the electron did not sing. In the triode valve, however, the electron sings. This phenomenological *realization* occurred at a precise point when mathematical and technical development was coming to maturity.
>
> *(Bachelard 1938/2002: 246)*

Indeed, Bachelard dubs his philosophy of experiment "technological realism" (Bachelard 1934/1984: 5), by which he means a "worked realism", one in which experimental work remains "closely dependent on a progressive rationalism" (Bachelard 1951: 89). Bachelard's twin ideas of "applied rationalism" and "rational materialism" are thus part of a larger attempt at overcoming the traditional opposition, in philosophy, between empiricism and rationalism and to conceive the relationship between theory and experience as a fully dialectical one. Rationalism, rather than representing a detached perspective, becomes a "dialogical philosophy" when it seeks both realization and validation through technical experience (Bachelard 1947/2021).[5]

## Regions of knowledge

The idea that every "region" or domain of knowledge has its own methods and standards of rationality can, to some extent, be traced back to Auguste Comte (Chapter 14), who believed that each scientific domain has its own canons of investigation (e.g. Comte 1835: 400–401). In this respect, we can identify one of the aims of Comte's classification of the sciences as underscoring the diversity of reality as such and the specificity of the methods we use to investigate it. One could easily argue that, unlike neo-positivism, both French and English forms of the original 19th-century positivism were inspired by pluralism. William Whewell, not dissimilarly from Comte, founded the "philosophy of the sciences" (note the plural) in the 1830s upon a pluralist conception of scientific methods (Whewell 1847: 2; see also Chapter 10 here).

Since *Le nouvel esprit scientifique* (1934), Bachelard opposes Meyerson's idea of a "general and unchanging reason", favoring, on the contrary, what he calls an "open-minded rationalism" (*rationalisme ouvert*, Bachelard 1934/1984: 173). In 1936, Bachelard develops the idea

of a "super-rationalism" which opposes itself in a "polemical" way to a kind of rationalism which is, on the contrary, "scholastic" (*rationalisme scolaire*) (Braunstein 1972: 7). A few years later, in 1940, he concludes *La philosophie du non* by arguing that "the traditional doctrine of an absolute, unchanging reason is only one philosophy, and it is an obsolete philosophy" (Bachelard 1940/1968: 123). For Bachelard, rationalism holds value only when it diversifies itself through specialization: "a scientific culture without specialization would be an ineffective tool, like scissors with dull blades" (Bachelard 1951: 12). In *Le rationalisme appliqué* (1949) Bachelard remarks that "few thoughts are philosophically more varied than scientific thought" and that philosophers of science should order this variety (Bachelard 1949: 160). It is here that Bachelard introduces the concept of "regional rationalisms" in order to underscore the existence of different regions in the organization of knowledge, reflecting the open and plural features of the continuously evolving human mind. Bachelard here plays with Husserl's idea of "regional ontologies", and, as in the case of "phénoménotechnique" above, the parallelism is meant to highlight the originality of the approach of the former compared to the latter. Contrary to Husserl, Bachelard does not aim to reduce regional forms of rationalism to a single and general eidetic science of physical nature.[6] Bachelard thinks that regional rationalisms must be linked to a "general rationalism", but this relation can be carried out in two different ways. One is the foundationalist and fixist model, defining rationality a priori once and for all, where all regions all knowledge are reduced to an underlying rationalism of a more general form. The other model is what Bachelard calls an "integrating general rationalism", connecting different kinds of experience a posteriori. This latter kind of model, which Bachelard explicitly endorses, also acknowledges the social nature of scientific knowledge, being a form of co-rationalism resulting from the coming together of the "workers of the proof" (*travailleurs de la preuve,* Bachelard 1949: 56). Bachelard's epistemological regionalism, thus, amounts to the view that:

> It is obvious that two theories may belong to two different bodies of rationality and may oppose one another on certain points while remaining valid individually within their own body of rationality. This is an aspect of rational pluralism which must remain obscure to those philosophers who insist upon believing in an absolute and invariable system of reason.
>
> *(Bachelard 1940/1968: 120)*

Bachelard applies this idea to his analysis of what he calls "electrical" and "mechanical" rationalisms (Bachelard 1949). Despite mechanical rationalism being in many ways "outdated" compared to electrical rationalism, both remain valid as two different viewpoints that can be applied to the same portion of reality. It is possible to find some antecedents of this pluralist view of science, for instance, in Heinrich Hertz's (1857–1894) idea, formulated in *Principles of Mechanics* (1894), that one can develop different and even inconsistent representations of mechanics that are nevertheless equally valid in terms of prediction and explanatory power. Generalizing Hertz's "picture theory", Duhem and Henri Poincaré (Chapter 15) famously concluded, respectively, that scientific theories are underdetermined with respect to reality and that scientific hypotheses and principles are arbitrary conventions chosen not because they are true (they in fact can be neither true nor false) but because they are convenient.[7] However, Bachelard harshly criticizes both Poincaré and Duhem, whose positions he dismissed as forms of "pragmatism" and "educated skepticism" respectively. Bachelard rejects the ideas that theories are underdetermined and scientific hypotheses are

conventions, holding firmly to the values of truth and objectivity in science (see Fabry 2019). In his view, science is objective, not despite but precisely because of its continuous structural mutations. Among the positions developed in the framework of the so-called "pluralist turn" in Anglophone history and philosophy of science characterizing the last decades of the 20th century, Bachelard seems to align quite closely with forms of "integrative pluralism" like that of ~~Sandy~~ Mitchell, which see distinct approaches being integrated locally for the explanation of phenomena (Mitchell 2022).

After Bachelard, regionalism remained a defining trait of the "French style in epistemology", as it was later endorsed, in particular, by Canguilhem and Foucault, among others (Braunstein 2002; Jacob 1991). According to Canguilhem, whereas philosophy of science is a *Wissenschaftslehre* whose aim is "the unification of knowledge, at least through its method", epistemology instead should be understood as a "special" or "regional study" consisting in "critical analysis of the principles, the methods and the results of a science". This critical analysis entails, as such, an "assessment of the results in relation to the methods, and of the methods, in turn, in relation to the principles" (Canguilhem 2015: 1098). Inevitably, this more open approach to the variety of scientific forms of inquiry diversified the repertoire of philosophy of science, displacing physics as "queen of the sciences" and bringing new attention to biology, the life sciences, medicine, and the human sciences. In this light, Canguilhem defends the autonomy of a "biological rationality", framing it as independent of and irreducible to the mechanistic framework of the physical sciences (Canguilhem 1965).

## The epistemologist-judge

The question of whether and how to combine philosophy and history was a major preoccupation for a generation of French intellectuals who gained academic recognition at the turn of the 20th century. Rey, founder of the IHST in 1932, conceived "historical epistemology" as the "documentary research" based on "the totality of the historical observations that are necessary to found a general exact view of the different sciences" (Rey 1907: 9). Attempts at supplementing epistemology with historical and "documentary research" found allies in Lucien Lévy-Bruhl's history of mind (1857–1939) and Henri Berr's (1863–1954) "total history". The complementarity between the "general philosophy of science" carried out at the IHST and the "historical synthesis" pursued at the *Centre de synthèse* was reflected by a fruitful dialogue among historians, historians of mentality, epistemologists, and historians of science (see Chimisso 2008). However, by taking general historiography as a negative counterpoint in order to define the nature and task of a history of the sciences, Bachelard's reflection marks a decisive change in this respect. The aforementioned dialogue was interrupted during Bachelard's directorship of the IHST (Conry 1983; Chimisso 2001) – signaling the reorientation implied by his approach.

The starting point of the new historiography developed by Bachelard, and explored since his early works, is the idea of a straightforward link between historicity and objectivity. Bachelard's dissertation addresses the concept of scientific approximation largely through the frameworks offered by the mathematical and experimental sciences. Bachelard links such scientific approximation to the level of objectivity science is able to achieve. From this perspective, scientific objectivity is not a given; rather, the processes of "objectivation" are what defines the progress of science: For Bachelard, scientific approximation thus becomes emblematic of rational rectification, and, by the same token, of the very principle of scientific progress (Bachelard 1928: 300).[8]

Building on these premises, a new kind of history of science is outlined in Bachelard's first major book, *Le nouvel ésprit scientifique*. Taking general history – that is, histories of human facts of all kinds, including military and economic – as a negative counterpoint enables Bachelard to redefine the history of the sciences. He maintains that the fact that knowledge has a history is confirmed by the ways in which the very structure of our minds gets changed by "the revolutionary character of modern science" (Bachelard 1934/1984: 171). This reveals a fundamental difference, for Bachelard, between the history of science and "human history" (Bachelard 1934/1984: 172). What Bachelard calls human "passions", "prejudices", and "impulses of the moment" are "primary illusions" constituting a "theatre of eternal recommencement". Bachelard suggests that we can reconstruct the history only of rational and scientific thought – two terms he found synonymous – because, unlike ordinary knowledge, common sense, and the themes of the imagination, they alone involve processes of approximation and conceptual rectification. Considering the non-rational side of human nature relatively constant throughout history, Bachelard conceives the role of the general historian as understanding and accounting for the passionate and impulsive reasoning motivating the actions of human beings in very distant places and times.[9] Unlike general human history, for Bachelard science never starts over: it only moves forward, and the history of the sciences must reconstruct the history of scientific ideas – i.e., ideas that have been rectified, enlarged, completed, and "definitely outstripped the limited shaky principles on which they may have been once based on" (Bachelard 1934/1984: 172).

Taking this as his point of departure, in *Le nouvel esprit scientifique*, Bachelard introduces one of the cornerstones of his epistemology: the notion of a gap separating scientific knowledge from common, everyday experiences. Bachelard later dubs this idea "epistemological rupture" (Bachelard 1949: 104). Contrary to Meyerson, Bachelard saw no fluid passage or substantial continuity between common, everyday experience and scientific knowledge, but a sharp break. In this sense, Bachelard argues, science is not the "pleonasm of experience" (Bachelard 1949: 38). Accordingly, he undermines the assumption of a continuity between immediate perception and scientific explanation. Scientific knowledge not only "exceeds" or "overrides" ordinary perception, it also establishes itself against it, becoming scientific to the extent to which it denies and rejects reliance on mere perceptible experience. This "polemical" or "dialectical" understanding of epistemological rupture is reflected in Bachelard's historiography: he argues that when a new theory supersedes an older one, it rejects (at least in part) the content of the older theory as non-scientific, or rather, as closer to the domain of common experience than to proper scientific knowledge. Bachelard's historiography thus stands out with respect to "continuous" epistemologies such as those of Meyerson and Duhem by claiming that scientific thinking does not develop in a continuous and cumulative manner but via mutations, often sudden, which cause radical shifts in conceptual frameworks.

Echoing Comte's theory of the "three stages" (the religious, metaphysical, and positive states), in *La formation de l'esprit scientifique*, Bachelard divides the history of thought into three epochs separated by sharp breaks. Bachelard thus distinguishes among a prescientific historical stage spanning roughly from classical antiquity to the 18th century, a scientific stage, extending from the end of the 18th century to the early 20th century, and the age of a new scientific mind, symbolically commencing with Einstein's writing on relativity in 1905 (Bachelard 1938/2002).[10] One of the seemingly paradoxical aspects of this periodization is its framing of the "scientific revolution" and Galileo's work – which, since Koyré, have occupied a central place in history of science, especially its Anglophone versions – as pre-scientific, since for Bachelard proper science emerged only in the 18th century.

Alexandre Koyré famously drew upon Bachelard's notion of "intellectual mutation" (Koyré 1966a: 11) to challenge Duhem's continuous account and highlight the radical novelty of Galileo's mathematization of the world.[11] However, Bachelard's and Koyré's proximity with respect to the question of ruptures in science is only apparent: indeed, for Bachelard, an epistemological rupture's "temporal" nature is a consequence of its being "epistemological", reflecting a break between scientific and ordinary knowledge (Gayon 2003). In Koyré, such idea of epistemological rupture is less central; he moreover considered history of science as continuous with other forms of knowledge and systems of beliefs, especially philosophy and religion.[12] Furthermore, Koyré champions a purely historical history ("histoire proprement historienne"), according to which the past would be interpreted on its own terms – or, in other words, as objectively as possible. He conceives the history of science, in particular, as an essential means "to relocate the works examined in their intellectual and spiritual milieu, and to interpret them in function of the mental habits, the preferences and the aversions of their authors" and, thus, "to study errors and failures with the same attention as successes" or achievements (Koyré 1966b: 14).[13] This, however, is contrary to Bachelard's idea of a "recurrent" historiography, that is, of a history of science written from the point of view of the present.

Bachelard's history of science is "recurrent" to the extent to which it is "judged" (*histoire jugée*): "a history whose task is to distinguish error from truth, the inert from the active, the harmful from the fertile" (Bachelard 1951: 24). Unlike the general historian, the historian of science has an obligation to formulate a judgment of events in the history of science and thus cannot be "objective" or "neutral" (Bachelard 1951: 24). The "historical dialectics" of scientific thinking constitutes a tension between what Bachelard calls a "lapsed history" (*histoire perimée*) and a history "sanctioned by actually active science" (*histoire sanctionnée*) which is continuously "done and redone" (Bachelard 1951: 24). Bachelard tasks epistemology with discriminating between what is lapsed and what is sanctioned in the history of thought. In this respect, as Bachelard argues, the history of phlogiston theory is lapsed and a

> rationalist cannot take interest in it without a certain bad conscience. An *epistemologist* cannot take interest in it if not because he finds in it reasons for a psychoanalysis of objective knowledge. An *historian of the sciences* who takes pleasure in it must know that he works on the paleontology of a lost scientific mind.
>
> *(Bachelard 1951: 25–26)*

Black's notion of *caloric* and *specific heat*, on the contrary, is part of a sanctioned history.

When Bachelard alludes to Louis de Broglie's wave mechanics as "one of the greatest syntheses of all times" (Bachelard 1951: 21), he marks a difference with the program advanced by Berr and his *Centre de synthèse*. In Berr's vision of "total history", science loses its specificity and becomes one element in a complex canvas potentially comprising all sorts of human intellectual and practical activity. For Bachelard, on the contrary, only modern science can provide moments of synthesis in which past knowledge is apprehended on entirely new bases (see Chimisso 2001). The introduction of wave mechanics is one of the strokes of genius Bachelard considers "epistemological acts" (*actes épistémologiques*), allowing for the overcoming of epistemological obstacles and the construction of an actually scientific theory (Bachelard 1951: 23, 25). However, Bachelard explicitly acknowledges that the "recurrent light" might not project onto the past of some scientific branches, such as physics and

chemistry, in the same way that it does onto mathematics and that one needs a certain degree of "tact" to be able to handle possible recurrences (Bachelard 1936/1972: 143).

Bachelard's approach to the history of science was highly influential among French historical epistemologists, inspiring both criticism and reformulations in subsequent interpretations. This is the particular connotation which, according to, Bachelard gave to a "French style in the history of science", which can be traced back to Comte and whose originality lies in epistemology's appeal to a "philosophical history" understood as a critical or "valorized" history (Canguilhem 1968: 63). According to Canguilhem, the history of the sciences should function as a tribunal in which the epistemologist, in the role of the judge, teaches the historian "the most recent language spoken by some science" (Canguilhem 2005: 200).[14] In turn, at the root of Foucault's ideas of writing a "history of the present" and of doing a "historical ontology of ourselves" as subjects of knowledge, power, and ethics resides the idea of "trapping our own culture" (*piéger sa propre culture*), which in Foucault is inspired by Bachelard (Foucault 1972/2001: 1250).[15] In conclusion, it is possible to see how Bachelard's reflections not only played a pivotal role in the transformations characterizing the French epistemological field of the 20th century, but also how a closer engagement with them reveals fruitful insights in all three turns (historical, pluralist, practical) characterizing Anglophone post-positivist philosophy of science.[16]

## Notes

1 Bachelard never used the term "épistémologie historique" to describe his work and this identification is mainly due to Dominique Lecourt's seminal work (Lecourt 1969).
2 Bachelard wrote reviews of Karl Popper (Bachelard 1935–1936a), of Hans Reichenbach (Bachelard 1935–1936b) and of Hans Hahn (Bachelard 1935–1936c). On Bachelard's critical reception of neo- and post-positivism see Leroux (2002).
3 This neglect is perhaps a result of a larger "cultural barrier" between (especially French) historical epistemology and analytic philosophy of science (Brenner 2015).
4 For a discussion of Bachelard's reception in the context of Anglophone "new experimentalism" and in the "science wars" see Simons and Vagelli (2021), Potters and Simons (2023) and Fabry (2024); see Chapters 7 and 38 here.
5 For a discussion on how Bachelardian themes in the philosophy of experiment traveled through the works of especially Francophone epistemologists of the second half of the 20th century see Simons (2018).
6 For this reconstruction of the steps leading Bachelard to the notion of "regional rationalisms" see Braunstein (2013).
7 The "pragmatic" conception of physics was rather an independent and "simultaneous discovery" by Hertz, Poincaré and Duhem, more than a case of influence of the former on the two latter.
8 Unlike Popper's refutations, Bachelard's conceptual rectifications have truth as their horizon.
9 With notable exceptions (namely Althusser and Foucault), this rather narrow and traditional understanding of historiography aligns with a broader neglect or dismissal of the discipline of history from Bachelard onwards by scholars associated, to varying degrees, with historical epistemology. Gilles-Gaston Granger, for instance, claimed that history, considered as an autonomous discipline, is not a science in the proper sense (Granger 1960/1983).
10 The Comtean model of a three-stage historiographical scheme was widespread in France at the turn of the 20th century – Marcelin Berthelot's *Les origines de l'alchimie* (1885) and Léon Brunschvicg's *Les ages de l'intelligence* (1934) are other instances employing this model (see Chimisso 2001: 131–32).
11 Koyré's notion of scientifsic revolution was in turn popularized in the Anglophone world by Thomas Kuhn. While Francophone readers have generally perceived Bachelard as very different from Kuhn the two have not unfrequently been associated by Anglophone scholars; see Simons (2017).

12 Bachelard's notion of epistemological break had a positive reception and was widely applied, especially in France. Althusser radicalized it into the concept of *coupure*, in order to account for the introduction of historical materialism as a science of history (Althusser 1969). Bourdieu, Chamboredon, and Passeron applied this—as well as other Bachelardian notions—to the sociologist's task of forming a scientific view of the social world against the background of the common sense and the corresponding naive language of social agents (Bourdieu, Chamboredon, and Passeron 1968/1991).
13 Braunstein rightly notes that this quote by Koyré reads like an early formulation of the "principle of symmetry" of the Edinburgh school (Braunstein 2002).
14 The differences between Bachelard's and Canguilhem's approaches are primarily due to the sciences to which they dedicate their respective analyses. Their distinct forms of presentism have been aptly described as "normative" and "critical," respectively, by Loison (2016).
15 Bachelard's recurrent historiography interestingly resonates also with more recent presentist histories of science (e.g. Chang 2021). For its criticism, on the contrary, see Roger (1995).
16 Portions of Section 2 of this chapter have appeared in Italian as Vagelli (2017), portions of Section 3 have appeared as Vagelli, Loison and Diaz (2021), and portions of Section 4 have appeared as Chapter 5 in Vagelli (2024).

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