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CHAPTER 6
Philosophies of science

Mach, Duhem, Bachelard

Babette E.Babich

THE TRADITION OF CONTINENTAL PHILOSOPHY OF SCIENCE

If the philosophy of science is not typically represented as a 'continental' discipline it is nevertheless historically rooted in the tradition of continental thought. The different approaches to the philosophy of science apparent in the writings of Ernst Mach, Pierre Duhem and Gaston Bachelard suggest the range of these roots. But for a discussion of the tradition of continental philosophy of science—as the term 'continental' characterizes a contemporary style of philosophic thinking—it is important to emphasize that while Mach, Duhem and Bachelard may be said to be *historically* continental, a properly continental-style philosophy of science should not be ascribed to any one of them. Contemporary philosophy of science is pursued in what is largely an analytic or Anglo-American-style philosophic tradition. And Mach, Duhem and Bachelard made the formative contributions for which they are known in the philosophy of science within this same almost quintessentially analytic framework.[1]

Nevertheless, this very necessary historical precision is itself witness to a changing circumstance in mainline philosophy of science. Although continental philosophy has been marginalized in professional philosophy in general, and where this marginalization has perhaps been greatest within the philosophy of science, the very centre would seem to have shifted. In past years, traditional philosophers of science have begun to broaden their analytic conception of the philosophy of science to include approaches compatible with or even drawn from continental styles of philosophy. Such approaches reflect the philosophical reflections on science expressed from the tradition of important individual continental thinkers such as Edmund Husserl (Gethmann, Heelan, Orth, Rang, Seebohm, etc.) and Martin Heidegger (Gadamer, Heelan, Kisiel, Kockelmans), Habermas and Foucault (Radder, Rouse, Gutting), and even Friedrich Nietzsche (Babich, Maurer, Spiekermann). In this context, the philosophical reflections on science to be found in Mach, Duhem and Bachelard may be mined for what should prove to be a productive historical foundation between these two traditions addressed to a common focus. Exemplifying such a common focus, the philosophy of science is not inherently or essentially analytic if it is also not obviously continental.

The question of stylistic conjunction between continental and analytic philosophic perspectives is complicated and, before it can be addressed, one further preliminary clarification is necessary. Because of the possibility of geographic confusion, it must be emphasized that the rubric 'continental' in the context of the philosophy of science does

not pertain to the geographic locus of the European continent except historically and circumstantially. Despite German and French scholars interested in specifically continental approaches to the philosophy of science in contemporary European philosophy, the character of the philosophy of science is decidedly analytic. It is telling and to the point in this last connection that Wolfgang Stegmüller, familiar as he was with traditional philosophy including phenomenological approaches, could find the appeal of analytic philosophy for a formalist and foundationalist interest in scientific theories so inspiring that he devoted his own life to its dissemination and through his influence analytic styles of philosophic thought consequently assumed their current leading role in German philosophy of science. In turn, this means that continental philosophy (and philosophy of science) remains as professionally marginal on the 'continent' as in English-speaking scholarly domains.

But if not defined as the dominant tradition in philosophy and if not a matter of geographic reference, continental philosophy (especially with respect to philosophic reflection on science) is also a multifarious tradition and not a single style or school. Just as Rom Harré could speak of 'philosophies' of science,[2] it is best to speak of 'continental philosophies' and hence of 'continental philosophies of science'. Not necessarily linked by 'family resemblances'—for example, Husserlian-influenced thinking bears almost no resemblance to Habermasian or Foucauldian social, critical theory—what is called 'continental philosophy' comprises several conceptual traditions and reflects a manifold of differing styles of philosophy with cross-disciplinary influences and applications. But one general characteristic might be said to be a strong historical sensibility. This sensibility distinguishes continental philosophic styles from analytic (progress-oriented and often expressly ahistoricist and sometimes expressly anti-historical) styles of philosophy. A critically reflective historical sensibility in addition to an explicit reference to lived experience—the *life-world* of Husserlian and Diltheyan usage—indicates some of the major advantages to be brought by continental styles of philosophy to the broader and general philosophic project of reflection on science.

It is this historical dimension and reference to life (practice, experience, etc.) that makes continental styles of philosophy so important for the philosophy of science today. Since the radical critique of the received, analytic style of modern philosophy of science through the writings of N.R.Hanson and the work of Thomas Kuhn and Paul Feyerabend, contemporary philosophy of science has been increasingly transformed by an intensified and today decisive sensitivity to the importance of historical and sociological studies of actual scientific practice. The turn to history so characteristic of Mach's as of Duhem's philosophic writing on science, witnessed by their valuable contributions to the history of science, and implicit in Bachelard's reading of the culture of science, has come to be recognized as an irreducible component of the philosophy of science. In the same way, the resources of continental philosophy with a tradition of reflection on history seem increasingly essential to the practice of the philosophy of science beyond stylistic differences.

As *fons et origo,* the shared destiny and origin of continental philosophy and analytic philosophy is evident in a recent trend reviewing the connection between Husserl and Frege (Hill, Wiener, Cobb-Stevens, Dummett), suggesting that Husserlian-style philosophies of science may go furthest towards bridging the stylistic gap between

analytic and continental philosophy. Likewise it is significant that the philosophy of technology, related to the philosophy of science because of its importance for reflection on experimental science, not only features continental practioners (Ellul, Ihde, Jonas, Schirmacher, Winner, Zimmerman) but is in its rigorously philosophic aspect a direct resultant of this same tradition (drawing as it does on the work of Heidegger but also Ricoeur and Gadamer).

Although Mach's (as indeed Duhem's) positivist successors were ultimately to disregard his concern with history in their focus on the formal analysis and logical reconstruction which characterizes the hypothetico-deductive account of theory formation and justification and which in its most developed form came to be known as the 'received view', recent reviews of Mach seek to examine his philosophy of science in terms germane to its own reflective scientific constellation and philosophical project (Feyerabend, Haller) rather than merely in terms of its influence on the logical empiricist tradition of the philosophy of science (beginning with Frank). Thus a reassessment of Mach's philosophy of science stresses his historical interests, while Feyerabend emphasizes aspects in his work which anticipate the insights of Hanson and Kuhn (as well as Michael Polanyi who is, according to Alasdair MacIntyre, significantly underacknowledged in this connection)[3] in Mach's sensitivity to the element of finesse (or in Polanyi's language: 'tacit knowledge'). Discussion of the role of tacit knowledge or finesse represents the researcher's 'art', an an which, if we follow Mach's words, is *unteachable* in the sense of being inherently unamenable to the programmatic Baconian project and which project, conversely for its part, was held by Bacon to have its singular advantage in being manageable by underlabourers—that is, by technicians literally, as Bacon has it: without 'wit'. For Mach, precisely such a programmatization (automatization, industrialization) is not desirable even if it were possible. We may note that the actuality of what Derek de Solla Price called 'big science' has long demonstrated that such 'programmatization' is possible and Hugh Redner details the same in his study of giant, industrial-sized science.[4] Against the artless routinization of science, Mach held that an unteachable 'art' must be indispensable for the practice of experimental science because, in Mach's conception of scientific inquiry, it is the *sine qua non* of invention and discovery.

A turn to history and the role of the experimenter's art is not the only parallel resonance between continental philosophies of science and traditional analytic approaches: there are others. Despite stylistic differences, analytic and continental styles of philosophy share a common future as complementary approaches to the philosophy of science where both disciplinary styles can enhance one another. But what is inevitably more important than the prospects of such stylistic reconciliation on a scholarly level, it now seems eminently clear that the philosophy of science cannot be conducted from an analytic perspective uninformed by the hermeneutic turn or, as analysts prefer to speak of it: the *interpretive* turn (Hiley *et al*). In concert with the phenomenological turn (to the things themselves), the interpretive, hermeneutic turn represents the foundation of continental thought. And it goes without saying, or calling it hermeneutics, that the interpretive turn is a turn of thought in which, like the historical turn, the reflective advantage of continental philosophy comes to the fore.

In both existing and possible expressions, continental philosophy of science includes

approaches drawn from the larger tradition of phenomenology (as found in the works expressed by Hegel, Husserl, Heidegger, Merleau-Ponty) as well as hermeneutics (beginning with some say Vico, but certainly with Schleiermacher and Dilthey, and also Heidegger, Gadamer, Betti, Gramsci, Ricoeur). Continental philosophy also reflects the influence of structuralism in linguistics, semiotics, and literary criticism and psychology, as well as the Heidegger-inspired *Daseinsanalyse* and existential psychoanalysis (Piaget, Binswanger, Boss, Fromm, Merleau-Ponty, Sartre and Lacan). Related philosophic styles of deconstruction and recent postmodern conceptions of philosophy (Foucault, Derrida, Lyotard, Baudrillard) have had a decisive influence on late twentieth-century philosophic reflection on science in line with the hermeneutic perspective (Heelan, Kockelmans, Kisiel, Hacking, Böhme, Gadamer, Bubner). With specific reference to the philosophy of the social sciences, particularly representing the Frankfurt school, which often incorporates analytic-style distinctions in its focus on language and discourse (Habermas, Apel, Tugendhat), characteristically 'continental' influences are traced in a variety of lineages to Hegel or Schleiermacher, Marx or Feuerbach (Althusser, Bhaskar, LeCourt) and Kierkegaard or Dilthey, Heidegger, Weber, Simmel.

As representatives of nineteenth- and early twentieth-century empiricism and positivism, the particular names Ernst Mach (1838–1916), Pierre Duhem (1861–1916) and Gaston Bachelard (1884–1962) have of course and as already noted much more than a merely historical significance. In analytic philosophy of science, an ongoing tradition of reinterpretations of their work continues to influence the current linguistic or theoretical crisis in analytic philosophy and semiotics/semantics of scientific theory (Duhem not only as represented by W.V.O.Quine but also Stanley Jaki) as well as, on the other hand, the current emphasis on experiment representing the counter-absolutist turn to the history (and historiography) and practice of science in the philosophy of science (specifically Mach, as represented by Feyerabend and others, and Bachelard—and in routine conjunction with analyses of Michel Foucault—for Bruno Latour, Ian Hacking, Mary Tiles, Gary Gutting).

MACH AND THE POSITIVIST CONNECTION: FROM ELEMENTS TO PHENOMENOLOGY

Ernst Mach was born in 1838 at Turas, formerly in Moravia—a region to be found in Bohemia, Silesia, and lower Austria which later was to become part of the modern republic of Czechoslovakia and is now part of the Czech republic. He studied in Vienna, teaching physics there in 1861, becoming professor at Graz in 1864, then at Prague in 1867, finally at Vienna in 1895. In 1901, upon his appointment to the upper house of the Austrian Parliament, Mach gave up his Vienna chair in the history and theory of inductive science. He spent the last three years of his life living with his son, Ludwig Mach and died in 1916 at Haar, near Munich.

At the risk of inviting distracting historical confusion, the above listing of the details of the historical name-changes concerning Mach's original nationality and the proper name or country of his birthplace—where names such as Moravia, Bohemia, Silesia, Lower Austria or, indeed, Czechoslovakia do not *currently* denominate legitimate nations within

today's Europe—dramatizes the fortunes of the Austro-Hungarian empire and eastern Europe as well as the philosophy of science conceived within the broad European tradition of natural philosophy. Although this is also given as Galileo's achievement in historical accounts of science, it is usually claimed that the tradition of natural philosophy was transformed by Newton himself into modern physical science. But this is only to say that the practice of science (*natural* science) came to be regarded as identical to the practice of the more speculative and often explicitly metaphysical tradition known as natural philosophy, and, conversely, that the practice of natural science was identified with natural philosophy. By the turn of the century, the project of the philosophy of nature was identified with the project of natural science. In Mach's day and well before, then, philosophy (including the philosophy of science or natural philosophy) was not thought to be necessarily separate and distinct from (understood as a business of reflection, interpretive or speculative, either subsequent to or independent of) the physical or natural sciences in both theoretical and experimental manifestations as Duhem and more recently Jardine and Crombie have shown. As Kurt Hübner has it, 'theory of science coming into prominence at the turn of the century was still closely tied to the study of the history of science. Names like Mach, Poincaré, La Roy and especially Duhem clearly bear witness to this. However this development ceased to follow the path opened up for it by these men.'[5] Here we may add that the divisions between philosophy and science and between philosophy of science and other kinds of philosophy were not always the same. Thus the debate between Hobbes (a speculative philosopher not merely a theoretician) and Boyle (an experimentalist not merely a physical scientist) or Berkeley and Newton were not regarded by either the participants or their contemporaries as taking place across, let alone mixing, categories (of philosophical speculation or hypothesis and scientific experiment and theory). For Mach and Duhem, the importance of philosophic reflection was to be evaluated with respect to its contribution to the progress of science. Thus retaining a defining reference to and even identification with *natural* science (as) *natural* philosophy, *philosophia naturalis* acquired the methodological, historical and epistemological profile of what would later become modern philosophy of science. Around the turn of the century, as practised by Henri Poincaré and by Duhem, philosophy of science bore the name *critique des sciences* and this same science-critical emphasis (that is, philosophical critique expressed for the sake of scientific advance or progress) is echoed in Mach's empirio-criticism. Under the influence of Wittgenstein, Carnap and Schlick, Hempel's mature expression of the 'received view' of the philosophy of science or the hypothetico-deductive expression of professional analytic-style philosophy of science represents a decisive and increasingly bankrupt departure from this late nineteenth-century tradition of *critique des sciences* with its particular and explicit reference to science in practice.

Almost from its inception then, the analytic tradition of the philosophy of science lacked any reference to the historical 'fortunes' or 'scenes' of actual scientific inquiry (Jardine). If the 'new science' of the seventeenth century had involved a transformative turn (whether revolutionary and world-shattering as Koyré maintains or evolutionary and therefore less radical a transformation as Duhem and Crombie would argue) to experiment, analytic philosophy of science has so far found itself less able to complete the same turn. If the difference is between, as the Galileo experts have it, Platonic

(formal) speculation and Aristotelian mathematical (functional) science, philosophers of science have tended towards Platonism. The turn away from history characteristic of logical positivism was only an expression of this idealizing, analytic tendency.

Although Mach in particular was especially devoted to experiment and its context in the history of science, many analytic authors nevertheless hold Mach to have been responsible for the divorce of traditional philosophical (metaphysical) concerns from the historical sensibility of the application of philosophic reflection to scientific practice. This is a misprision of a devastating kind but it was a constitutive one: seminal for the professional development of analytic-style philosophy of science.[6] The separation between philosophic expression and the lived world characteristic not only of logical positivism but of the division between continental and analytic styles of philosophy is no accident of location or tastes, as the talk of 'styles' may suggest. Rather, a necessary consequence, it might be argued, of the self-definition of modern science (as distinct from medieval and ancient science), the gap between theory and practice has shaped the analytic tradition of the philosophy of science, while at the same time leaving the philosophy of science as a theoretical discipline (*qua,* philosophy) addressed to a particular theoretic practice (science) singularly unable to support the disjoint consequences of a separation between theory and historical practice.

Despite Mach's 'physicalism' or 'phenomenalism', the members of the Vienna circle, in the telling words of one commentator, 'wrote as though they believed science to be essentially a linguistic phenomenon'.[7] Hence this disposition to analyse 'language'—be it ordinary or logical language—together with a naive (non-historical, non-hermeneutic or ideal) view of *direct* observation (i.e., observation sentences) effectively limited the analytic concern of the philosophy of science to the analysis of theory, which last is the project of the received view or hypothetico-deductive nomological ideal of science (theory).

Such a focus on the elements of language—and not on the elements construed according to Mach's conception as *physical-physiological-psychological*—separates language and world. One obvious advantage of such a focus is the advantage of certainty. But this, its strength, to paraphrase Mach, and as is so often the case, is also its weakness. Philipp Frank, one of the founding members of the Vienna circle, who expressed the virtue of scientific analyticity, combining the essence of Mach's insights with Duhem's Kantian conventions, explains, 'the principles of pure science, of which the most important is the law of causality, are certain because they are only disguised definitions.'[8] If the essence of tautology or logical linguistic self-reference is not problematic when what is analysed is language use (the game or its rules), this same tautological expression becomes problematic when what is analysed must correspond to scientific facts or empirical matters. As Harré has observed, 'the philosophy of science must be related to what scientists actually do, and how they actually think'.[9] The imperative for such a correlative project between the philosophy of science and scientific practice, corresponding to the force of the socio-historical turn that comes after the linguistic turn, represents a much-needed philosophic mandate for the philosophy of science.

The revolutionary shifts, reversals and paradigmatic conflicts within the analytic tradition of the philosophy of science also correspond to the revolutionary shifts, reversals and paradigmatic conflicts in physical science. These witness to the need to

develop a 'new' philosophy of science appropriate to the 'new science'. But the history of science tells us that novelty is itself relative, for the history of science is just such a record of 'new' sciences. One of the first 'new sciences', that of Galileo and Newton (and Hooke and Boyle), inaugurated a tradition that has since developed beyond its initial programme. That tradition was the tradition of modernity (as the cult of the new), and if one can speak of postmodern science today that is just because the programme of modernity can no longer be viewed unproblematically. The fortunes of the 'new' science and enlightenment thought mirror the problem of modernity and postmodernity, the problem of the conflict between the grand narratives of science and society and the distintegration of the promise of those same narratives throughout the modern era. This is not unconnected to the new historical and social turns in philosophic thinking about the sciences. These turns are not a sign of the times so much as they reflect a tension interior to post-Galilean science. As Mary Tiles explains the dynamics of this internal tension in post-Galilean (or 'new') science: 'The new science was to be abstract and mathematical, but also experimental; it was to yield both enlightenment and mastery of nature. It was to strive for an objective, purely intellectual, value-free view of the world in order to improve the lot of mankind by rendering technological innovations possible.'[10] There is an inherent conflict in this juxtaposition of material, practical progress and ideal or objective knowledge. Today's post-analytic or 'new' philosophy of science is manifestly directed to an expression of the consequences of this conflict.

Here, with reference to Mach's own particular historical context, it must be observed that Mach's declared opposition to philosophy—even where such an opposition may be rendered on Pascal's account as the best affective precondition for the best kind of philosophy—is, if taken literally as applying to philosophy today, anachronistic. Mach wished to avoid identification with the more metaphysical fashions often associated with or characteristic of philosophy. But his reflection on science was nothing other than a philosophy (albeit a philosophy of nature). This point highlights the value of a return to history for the sake of the broadening illumination of context. And where the return to history represents Mach's own phenomenalist version of Husserl's phenomenological call to return 'To the things themselves!', it cannot truly be Mach who is to be blamed for the logicization of the philosophy of science.

In all, the history of modern philosophy of science may be said to begin at the juncture epitomized by Mach's biography; but the rupture between theory and experiment that followed from the increasing logicization of empiriocriticism or critical positivism related to the rise of analytic-style philosophy of science has no precedent in Mach. This point is essential if one is to understand the growing attention paid to Mach's historical emphasis along with his very prescient sense of the importance of the art of the researcher, of the technical and social flair essential for the practice of the experimental life of the sciences.

Mach was greatly influenced by Berkeley and Fechner as well as by Kant and Hume. His thinking on the logical 'economy' of thought was shared by Richard Avenarius and his views on the nature of science engaged not only the scientists Helmholtz, Kirchhoff, Boltzmann, Einstein and Schroedinger but also the American pragmatist philosophers James and Pierce. It has been suggested that Mach's concern was to understand experience. But this concern with experience was not the same as the anglophone preoccupation with sensation. It has already been noted that many authors also tend to

associate positivism's characteristic distance or alienation from the world with Mach's scepticism. Given Mach's sympathy with Berkeley and Hume, such an identification is not surprising. Mach's philosophy of science is commonly described as a 'sensationalism' or 'phenomenalism', expressed as an 'idealism', or by the catchwords positivist, empiricist, and anti-metaphysical. Endowed with the radical scepticism of a working scientist, as Mach was and because his sensationalism does not express an ontology as such, it is best to understand his perspective as fundamentally or even propaedeutically *heuristic*. Hence whatever metaphysical interests Mach may have had, they are not propositional but rather reflect his project of articulating what Paul Feyerabend describes as a non-foundational epistemology, and such an epistemology is not only essentially scientific but also represents the philosophic spirit of epistemology as such. In the same way, reference to a simplistic notion of parsimony, or *Denkökonomie,* linking that principle to an ontology, is misguided. And without emphasizing the extreme and today uncommon philosophical breadth of Mach's interests, the claim made in his *Analysis of Sensations* (1886) that 'the world consists only of our sensations' must be confusing. Again, Mach does not reduce the world to sensation so much as he finds the world *given in* and, as both Duhem and Bachelard would also stress, *knowable* only through sensation: 'Science does not create facts from facts, but simply *orders* known facts' *(Popular Scientific Lectures)*. It is this connection that suggests a natural affinity between Mach's elemental phenomenalism and Husserlian phenomenology borne out by Mach's initial (and then specifically continental) reception (Brentano, Musil, Dingler) and which has more than once been reviewed in its connections not only with Husserl but even with Nietzsche (Sommer, Gebhard).

Mach deliberately sought to distance himself from the metaphysical pretensions of traditional philosophy as well as those assumed (sometimes by scientists) in the name of science. Like Duhem, Mach eschews the claims to certainty which have come to characterize traditional scientific expression and serve as an identifying feature of today's analytic heirs to the logical positivist tradition of the philosophy of science. For Mach, as for Duhem and Bachelard, *enquiry,* conceived via experiment, was the benchmark of the scientific enterprise and a classical but not necessarily pyrrhonian scepticism was the best guarantee of such an enquiring or open attitude. But this scepticism did not mean that Mach gave up any claim to offer an account of the scientific knowing enterprise, with respect to either practice or progress. Hence William James upon meeting Mach in 1882 could write not only that he had 'read everything' but that he 'knew everything'. James was not merely impressed with Mach, polymath extraordinaire, but by Mach's *pragmaticist* turn, which is one way to understand the very practical but not ontological imperative guiding Mach's endorsement of a logical economy. In this way, Mach's thinking illustrates the continental spirit of philosophy as questioning conceived in that *authentic* sense charac-terizing what Martin Heidegger calls thinking and which Nietzsche critically pronounces as the highest scientific virtue: intellectual probity or *Redlichkeit*. In Mach's *Popular Scientific Lectures* (1882), starting from the axiom that 'Physics is experience, arranged in economical order', such a questioning or open-ended reflection means that a philosophic consideration of the goals of science following the ordering value of economy as a thought principle is not proposed as or purported to yield a finished system: 'In the economical schematism of science lie both its strength and its

weakness. Facts are always represented at a sacrifice of completeness and never with a greater precision than fits the needs of the moment.' This very Aristotelian practicality, which Gadamer has expressed in another context as the prudential core of hermeneutic judgment, works on Mach's account to exclude anything like 'absolute forecasts'.

Considered on its own terms, Mach's view is an *elemental* sensationalism, a factual, specifically non-factitious or empiri[ocriti]cism. Mach's thinking is radically sceptical. And it is a kind of conventionalism, like that of Duhem and Poincaré, which influenced the positivist protophysics of Dingler and the Erlangen school of Lorenzen's constructivism and its related development in evolutionary epistemology (Wuketis). But so far from the flat positivism of a reduction of the world to fact, Mach's 'mental mastery of facts' offers the only understanding to be had from or about those same 'facts', where the question of order or mastery in each case is hypothetical and ever subject to revision. This perspective in its historicist extension explains Mach's positivist appeal but an attention to the elemental mentality of this 'mastery of facts' shows its fruitfulness for current issues. This is evident in contemporary analytic philosophy of science after Kuhn and Feyerabend.

Thus Mach proposes that if the future of science may not be forecast as such (on pain of abandoning the open enterprise of science itself), its non-absoluteness may nevertheless be surmised and he suggests, in a fashion that is as Nietzschean as it is radically, elementally pluralistic, reflecting the spirit of what today has come to be called the 'new physics'—and what might likewise be named the 'new biology' and the 'new ecology'—that 'the rigid walls which now divide man from the world will gradually disappear; that human beings will not only confront each other, but also the entire organic and so-called lifeless world, with less selfishness and with livelier sympathy' *(Popular Scientific Lectures)*.[11]

It has been noted that Mach sought to articulate the project of science in terms of its history and its practical or working functionality. But Mach's particular historicism was that of a philosopher—in spite of his protests against such an identification, where, as was also noted in a preliminary way, these protests themselves must be interpreted with reference to Mach's own, historical, circumstantial context. As a philosopher, Mach's historical focus shows him as a positivist, in the original, pristine Comtean sense of the word.[12] Ian Hacking, in a timely effort to broaden the current flattened and negative reading of 'positivism' with reference to August Comte's original use of the term, defines *positivity* as 'ways to have a positive truth value, to be up for grabs as true or false'.[13] Positivistic to this extent then, not only was Mach a philosopher, but he was a quasi-analytic—if also as we have seen a proto-phenomenological and even hermeneutic—kind of philosopher. Moreover, Mach remained as consistently committed to expressing the logical and philosophical foundations of science as any member of the Verein Ernst Mach (which was in fact and significantly the original name for the Vienna circle) or the modern heirs of the logical empiricist tradition in analytic philosophy of science.

Yet it must be emphasized that Mach was committed to the positivist ideal of science, that is, in Hacking's Comtean sense, to its 'positivity' but not its sheer logical expression. Thus, and, as we shall see, like Duhem, Mach's critical analytic turn far exceeds anything like an exclusive commitment to the expression or clarification of scientific method or theory as an end in itself where he criticizes the working functionality of the latter. More

critical than Kant, Mach believes that there is no possibility of a priori knowledge *as such:* the basis of *all* knowledge is sense experience. Mach's *elementalism*—as his 'sensationalism' is best described as outlined above and following the letter of Mach's own account—repudiates the 'arbitrary, one-sided theory' which is implied in talk of 'sensations' or 'phenomena'. This is important, for what Mach repudiates as 'arbitrary, one-sided theory' focusing upon 'sensations' or 'facts' represents the idea of the self or subject apart from or as substrate underlying or undergoing such 'sensations'. In this way, Mach's elementalism mirrors the critique of the subject familiar to continental scholars and others acquainted with the works of Nietzsche and Freud, as well as Heidegger, Lacan and Wittgenstein. As the central tenet of Mach's psychology, the self is a bundle of elements, an expression which must be understood not as Locke or Berkeley would understand it but rather as signifying a fundamental continuity between the unit of the perceiving self, or the physiological (elemental) subject, and the mental matter of psychological (elemental) knowing and the physical (elemental) world. Physical, physiological and psychological, Mach's convertible elements comprise his elementalism. This continuity suggests the *intentional* commonality requisite for developing a phenomenological reading of Mach's 'sensationalism' in the line of Husserl. This same connection also suggests the relevance of Mach's thought for interpretations of quantum physics. Mach's principle, so important on Einstein's own account for Einstein's theory of relativity, implies the interdependence of all things—that is: relativity (Mach's own views concerning relativity are no matter in this context). Hence there is no need for an absolute frame of reference (whether Newtonian space or time) but only for a relative frame of reference. The law of inertia stated by Newton can be understood either from the perspective of the body at rest or motion or from the related perspective of external impingent forces.

Scientific laws for Mach are abstract, general, and in all we might say: *abbreviated* descriptions of phenomena. The value of such laws, the 'meaning' of such laws for Mach, as for Nietzsche and Wittgenstein, lies in their use: their value for prediction. This too is not an ontological statement. Since Mach is not concerned with absolute truth as is the more metaphysically inclined philosopher of science, he is free to share the physical scientist's focus on working utility. It was this dedication which led to Mach's notorious repudiation of unobservables (unusable—untestable) as explanatory components in the atomic theory of physics and chemistry. Needless to say this prejudice, like his emphasis upon the researcher's 'unteachable' art *(Knowledge and Error),* has acquired the triumphant patina of prescience which is the fruit of a convergence with contemporary science, for today's atomic theorists have since discarded the nineteenth-century mechanistical vision of the atom.

PIERRE DUHEM AND THE DAMNATION OF RELIGION: THE LIMITS OF ANALYTIC REHABILITATION

Pierre Maurice Marie Duhem was born in Paris in 1861, a son of a businessman of Flemish descent. Duhem's mother could trace her origins to the south of France and the village of Cabrespine, near Carcassonne, to the very house where Duhem himself was to

die at the age of 54. In 1882, Duhem entered the Ecole Normale Supérieure at the head of the yearly competition. Proving his initial promise, Duhem completed a dissertation in thermodynamic physics in only three years. But through no evident fault of the work itself, Duhem's dissertation was none the less rejected by a jury headed by Gabriel Lippman. Two years after this first academic frustration, Duhem would successfully submit another thesis in thermodynamics, to earn his doctorate (in mathematics). Duhem's rejected first thesis was not only subsequently published but published to a broad and approbative scholarly reception. We shall have cause to note below that the complicated circumstances of this rejection are important for understanding Duhem's intellectual and academic career. In 1887, Duhem became *maître de conférences* at Lille, where he taught physical mechanics. Following a pedagogic dispute at Lille, Duhem moved to Rennes in 1893, but soon afterwards took a chair at Bordeaux in 1895, which he occupied until his death in 1916.

Duhem's philosophic interest in scientific theories is seen in his still-influential 1906 book, *La Théorie physique: son objet, sa structure (The Aim and Structure of Physical Theory)*. Duhem, who shared Mach's belief in the vital importance of history for scientific progress, also made significant and substantial contributions to the history of science with his *Les Origines de la statique* (1905–6) and his voluminous study of medieval cosmology, *Le Système du monde* (1913–58), for the most part published posthumously and which has recently appeared in highly truncated form in English translation as the one-volume *Medieval Cosmology*.

If a discussion of place names can illuminate the changes necessary for an understanding of the transformation of natural philosophy into the kind of philosophy of science familiar today, the absent name of Paris is significant for understanding Duhem's intellectual position in that same tradition of the *critique des sciences*. For Duhem to all appearances had, with the submission of his first dissertation, opposed a then leading scholar, Marcellin Berthelot.[14] Duhem's biographers are largely agreed in reporting that the reasons for the jury's refusal of the thesis stem from the offence given to Berthelot in Duhem's theoretical repudiation of Berthelot's thermodynamical views on minimal work. And, indeed, more than a motive indicating a subjective and not an objective reason on Berthelot's part, we also have a tacit confession. In a 1936 biography written to secure support for the posthumous project of editing and publishing the remaining volumes (ultimately to number ten in all) of Duhem's *Système du Monde,* Duhem's daughter, Hélène, reported Berthelot's oft-cited professional edict which consigned (or better said, effectively damned) the Parisian-born Duhem to the provinces: 'This young man will never teach in Paris.'[15]

But to leave the question of the merits of Duhem's first dissertation to one side, and likewise to reserve the related question of the tactical wisdom of offending the leading scholar of one's day (for, as a recent biographer of Duhem's life and work, R.N.D.Martin, has observed, both are more properly questions to be directed to Duhem's teachers at the Ecole Normale than against Duhem himself), I would note that Berthelot's personal antagonism towards Duhem nevertheless retains resonant dimensions which exceed the indignant prejudice of the offended vanity of a leading Parisian scientist. For, betraying something more than a personal idiosyncrasy, Berthelot's views echo the general tenor of Duhem's philosophical reception, both then and now, where at least for

our times it may be assumed that questions of professional conviction and ego are not similarly relevant. Nevertheless, questions of personality, understood in the broad, psychological and, in Duhem's particular case, confessional sense, play an essential role. Hence it is not insignificant that we are informed again and again that Duhem was a Catholic. Thus the newly published contribution to Duhem scholarship by Duhem's foremost English-language commentator, Stanley L.Jaki, bears the title *Scientist and Catholic*. Jaki, himself a priest, certainly does not mean to underline this conjunction unsympathetically. But Duhem's religious faith is common stock in reviews of his philosophical merit. And an evaluation of the objective significance of Duhem's faith with respect to Duhem's historical circumstance is not easy. And Martin's study of Duhem's intellectual biography, appropriately subtitled *Philosophy and History in the Work of a Believing Physicist,* begins by adverting to the significance of the specific fortunes of Duhem's intellectual reception. Martin notes that Duhem's work is from the start clouded by a number of persistent critical reservations. Thus it is essential to underline the fact that a French scholar of importance as, beyond all dispute, Duhem must be accounted, should none the less be denied, as Duhem was denied, a Paris chair. Whereas Bachelard, born in the provinces, and mentioned here for the sake of contrast, would not be similarly denied this same token of recognition. The difficulty here in the case of Duhem, arguably the superior philosopher, surely the superior scientist, is to trace the proximate cause.

In the conflict with Berthelot, reservations concerning Duhem's achievements preceded Duhem's scientific and academic career. Martin sums up the general scholarly judgment with respect to Duhem's historical stature with the resounding ambiguity of an understated reservation as, in a word, 'problematic'. For many, Martin writes, Duhem was 'a brilliant maverick who continually got things frustratingly wrong: producing brilliant arguments against atomic explanations in physics and chemistry, a muddled instrumentalism in the philosophy of science, and a voluminous collection of misreadings of mediaeval Scholastics' ([6.50], p. 194). In general, for Duhem's biographical commentators and interpreters, that is for Martin, for Jaki, Roberto Maiocchi, etc., Duhem's problem was fundamentally and in its essence a religious one, and, like most confessional affiliations, this was one that cut two ways. Not only was Duhem's Catholic faith an obstacle to the largely Protestant ideals of modern science but Catholics were uneasy with his totally modern (and in the Catholic view 'modernist') opposition to neo-scholasticism. Duhem for his part was an iconoclast, and his position in the provinces was not such as to inspire him to restraint (Duhem, let it be remembered, despite his lack of a Paris chair, was a native Parisian).[16] He was particularly impatient with the neo-Thomism of the day, evident in the works of Jacques Maritain with his quasi-Aristotelian classification of the sciences. In the long run, what this meant was that Duhem could be dismissed as a Catholic apologist by non-Catholics while simultaneously being condemned as 'modernist' by the French Catholic intellectual elite.[17] And these reservations made on two sides were not the result of unthinking prejudice on one side or the other, but were in fact founded at least to some degree in both cases. For it is clear that the realist metaphysics and authoritarianism of the aims of the neo-scholastic movement in philosophy were undermined by the substance of Duhem's views. Conversely, Duhem's non-Catholic readers could regard Duhem's historical interest in

medieval science as representing little more than another version of neo-scholasticism. The historical researches of Crombie and others suggest that the problem requires a clearer understanding of the differences between historical eras rather than matters of faith, but Martin's observation that 'Duhem seems to have fallen between every available stool' ([6.50], p. 211) would seem to be the least one could say not only of Duhem but of the judgments made concerning him. What the new concern with history illustrates is the value of Butterfield's insight that a 'Whig interpretation of history' (or 'presentism' as it is also called)—that is, an interpretation of other eras from the perspective of one's own era—illuminates only one's own prejudices (and that only from the point of view of a subsequent historiographer) without shedding light on the period in question. History without hermeneutics is blind.

Against Koyré's reading of the revolutionary transformation from the medieval to the modern world-view, which corroborates the non-or anti-Catholic reading of Duhem's reactionary scholasticism, Jaki maintains that Duhem's sympathetic account of the scholastic opposition to Aristotelian philosophy of natural place suggests that this medieval perspective fostered rather than hindered the modern scientific turn such as that associated with, for example, Galileo's speculations concerning the role of impetus. Other scholars, such as William Wallace, have offered corroborating readings of the 'Galileo affair', showing the importance of taking Galileo's terms not in a putatively modern context (following the conviction of Galileo's visionary genius) but in their more patent and for the modern reader all the more tacit historical and that is medieval context.[18] Wallace's discussion of Galileo's use of the Latin term *ex suppositions* illustrates this point.[19] The problem is not only that readers from the perspective of modern (analytic) philosophy of science tend to translate *ex suppositione* as *ex hypothesi,* but that the perspective of the Catholic Church is automatically identified with that of an anti-modern, progress-retarding influence. This, in the apposite context of the contest between religion and science, shows the tenacity of the Whig interpretation of history. For this reason, Butterfield writes, 'It matters very much how we start upon our labours—whether for example we take the Protestants of the sixteenth century as men who were fighting to bring about our modern world, while the Catholics were struggling to keep the medieval or whether we take the whole present as the child of the whole past and see rather the modern world emerging from the clash of both Catholic and Protestant.'[20] For Butterfield the problem is the tendency to reduce the problem to one between Protestant and Catholic, between *enlightened* Whig and *darkage* traditionalist. To understand Duhem, one must go beyond confessional prejudice.

In fact, as Martin takes pains to demonstrate, Duhem must be characterized as a reluctant convert to his ultimately continuous account of the transition from medieval science to modern science. Duhem moved towards this view *in spite* of his own original views as a scientist working at the peak of the modern self-understanding of the sciences, that is, despite his typically scientific (high modern or scientistic) formation at the turn of the last century. According to science's own self-understanding then, and which is in part still true for scientists today, the transition from the (in Koyré's words 'closed') medieval view of the world to the ('open') modern world-view was—like the birth of the fully armoured Athena from the forehead of her father Zeus—a sudden, completely discontinuous or punctual, radical leap from classical and hellenic to fully-fledged

modern science. This view eclipsing the scientific value of the Middle Ages was as typical for the average scientist in Duhem's time as it can still be said to be true of scientists and of many philosophers today. Against the bias of this formation, it was less Duhem's religious faith, one could argue, than his rigorous education as a formal logician that brought him, indeed compelled him, to re-examine the historical record. In Jaki's view, a view now with considerable historiographical support, in addition to Duhem's axiom-atician's rigour, the record suggests that the medieval cosmological viewpoint worked not to obstruct the path to modern science in effect, where even Galileo's term *impeto* may be traced to Jean Buridan in the fourteenth century, but rather to further its advance. Duhem's reading of medieval science as an essential bridge between classical science and Galileo's inauguration of Newton's project of modern scientific thinking reflects a revolution, but the revolution for Duhem takes place in his own thinking, against his modern scientist's ingrained thought-style but in accord with his trained axiomatician's loyalty to the importance of first principles and logical coherence.

Duhem's argument stressed both subtlety and complexity, but it is clear that for him the key question for any theory or hypothesis was its utility in 'saving' the phenomena. On such accounting, of course, not only was Galileo a child of his times, indebted to the scholasticism of Oresme and Buridan, but Galileo's account was less successful than the Ptolemaic alternative. From this point of view, Cardinal Bellarmine's prudential caution may be read less as an illustration of jesuitry than as a representative of that kind of French common sense or Pascalian *bons sens* where the spirits of geometry *and* finesse intersect and for which, as both Martin and, years earlier, Dorothy Eastwood have argued, Duhem had a notable affinity. Yet beyond the still-unsettled questions of Duhem's personal reception, Duhem's significance for analytic philosophy of science is not in fact a subject of much debate owing to the prominence of the philosophers routinely listed as having responded to Duhem's influence, most notably Popper and Quine.

Duhem's argument against crucial experiments may also be seen to turn on his understanding of theories as axiomatic systems and his appreciation of the nature of such systems. For Duhem, physical experiments cannot refute isolated theories. Where alternative theoretical views are to be tested, an experiment designed to enable the experimenter to choose between them only confirms one hypothesis or another. But as an experiment confirms or refutes the theory and not the theoretical system, the results are inconclusive for not only may a subsequent experiment fail to confirm the theory, but a related experiment may refute a related theory; the experimenter is free to make ad hoc adjustments, and what has come to be called the 'theory-ladenness' of observations means that such adjustments may well be already or subsequently 'built into' the interpretation of the experimental results, without necessarily involving the awareness of the experimenter. Apart from such phenomenological hermeneutic questions as context-dependence and interpretation, the significance of the theory in any case is articulated only within the theoretical complex of which it is a part. Just as there are no isolated phenomena, there are no isolated theories but only theoretical systems. This interdependence points to the reason for Duhem's (as for Mach's own) conviction concerning the importance of history. Modification in the theory may preserve the system and vice versa, and an understanding of the system requires an understanding of the

original meaning of its terms. For Duhem, experiment is crucial, but neither falsification nor demonstration provides certain or sure tests of eternal, unchanging truth. On this point, it is the history of science which justifies Duhem.

Apart from Duhem's views on history and related to his views on theoretical indecidability, Duhem held a form of instrumentalism that was shared not only by Mach and Poincaré, but also by Kirchoff, Hertz, Bridgman, Eddington and the Copenhagen school of quantum physics. For Duhem, two aspects of theory must be distinguished, the explanatory and the representational. As far as Duhem was concerned, although scientists and philosophers of science of a realist bent regarded theories as explanation, the value of theory is ultimately its instrumental or conventional value. Instrumentalism is a view of scientific theories founded, as Karl Popper says, by 'Osiander, Cardinal Bellarmine and Bishop Berkeley'.[21] Linking Osiander to Cardinal Bellarmine, as most theoreticians stage this drama, it is clear that the great antagonist to such instrumentalism for Popper and for others is Galileo. And, as Ian Hacking puts it, 'Galileo is everybody's favourite hero—not only Chomsky and Weinberg but also Husserl.'[22] To say as has already been suggested that Galileo was not as radical or as ahead of his times as had been thought is to oppose the general conception of Galileo as a canonic scientific hero (or saint). This is the associative point MacIntyre makes (arguing in a different direction) when he speaks of Feyerabend's 'anarchism' as Emersonian in spirit, advocating 'not "Every man his own Jesus" but "Every man his own Galileo"'.[23] If Duhem is an instrumentalist, he also stands opposed to Galileo. And he cannot do otherwise. Duhem, with his claim that 'a law of physics is properly speaking neither true nor false' *(The Aim and Structure of Physical Theory),* is consequently one of the principal antagonists not only of Popper's realist-falsificationist view of physical theories but of all realist views of science.

Duhem's instrumentalism continues to be important for the present profile of the philosophy of science in the English-speaking world. For Duhem, the same physical law has a potentially different extension at different times owing to the historical development of these laws and their embodiment in experimental *praxis*. The meaning of a physical law is to be determined in the final analysis by the context of scientific practice and the scheme of related laws involved in determining the meaning of that law. This principle provides the basis for the underdeterminist perspective on the relationship between experimental evidence and theory and the constellation of related theories. Through the work of Quine and Davidson, this notion of underdeterminism led to the current position on theoretical indecidability that has done so much to bring analytic philosophy to a (theoretical) cul de sac if also, albeit indirectly, generating the current emphasis on the importance of experiment in discussions within analytic philosophy of science.

It is a testimony to the seminal character of the influence of both Duhem and Mach that it is today thought necessary to return to their philosophic understanding of scientific practice (as theory and *experiment/praxis*). This is not to say that they were in individual agreement among themselves but rather that each had distinct insights which similarly failed to be transmitted in subsequent debates. And the current urgency of an historical turn in the philosophy of science, clear since the work of Hanson, Feyerabend and Kuhn, is accordingly necessary largely if not only because of a correspondent refusal of history in mainline or analytic philosophy of science.

GASTON BACHELARD: SCIENTISM WITH A HUMAN FACE

Gaston Bachelard was born at Bar-sur-Aube in 1884. Bachelard's studies were conducted, as he himself was given to muse, under the sign of delay and he worked as a part-time mechanical technician for the French postal service until 1913 when he earned his *licence* in mathematics and science, becoming a teacher at the Collège of Bar-surAube. Upon earning his doctorate in 1927, he assumed the chair of philosophy at Dijon and was then called to the chair of the history and philosophy of science at the Sorbonne in 1940, where he remained until his retirement in 1954. He died in Paris in 1962.

Bachelard's philosophy of science is expressed as a 'dialectical rationalism' or 'dialectical naturalism'. Just as Duhem's anti-idealist conventionalism was read as conducive to the aims of materialism, although instrumentalist and thus inherently anti-realist, so Marxist authors such as Louis Althusser and Roy Bhaskar have read Bachelard's naturalism as a kind of dialectical materialism to be employed against ideological appropriations of science. Although the current interest in Bachelard's epistemology and consequently in his philosophy of science doubtless owes a good deal to Althusser, and without denigrating the value of Althusser's reading for Marxist or materialist epistemology, the Marxist reception of Bachelard's work and the word 'dialectic', if drawn exclusively from Althusser's programme, can be misleading (LeCourt). Still it should be emphasized that those working from Marxist perspectives have been far more assiduous in examining Bachelard's philosophy for its epistemic component than other traditionally analytic philosophers of science (Bhaskar).

Bachelard's emphasis is on a dialogical exchange, that is to say, a dialogue between the knower and the known, a dialogue between poetic and scientific discourse. This is not to be construed as inherently (or essentially related to) a dialogue between *poetry* proper and *science* proper. Instead the capital dialogical exchange is that between the scientist and the dreaming scientist himself:[24] the scientist and himself poetizing, or projecting (and thus 'dreaming' or effectively constituting or technically constructing) the world of scientific nature. Thus Bachelard wrote on the psychoanalysis of the history of the discovery of fire as a dialogue between psychoanalysis and that history to find *its* psychoanalysis metaphorically in (and of) the history of sexual desire. The metonymic association between the origin of fire (and electricity) and the fire (and electricity) of sexual passion points to a dialogue between image (the discovery of fire) and the human reflection or projection of that same discovery. Similarly, the philosophy of no, by which expression Bachelard seeks to characterize the openness of the scientific attitude, is a dialogical philosophy—or better a dialogical account—of scientific practice. To say that the scientist constitutes the phenomena, the objects of science, is not to describe a unilateral construction; rather the constitution is a formative, informative, reciprocal creation, a making of the scientist himself as much as a making (a projection or constitution) of the scientist's world. This exchange with the world of scientific or technical experience articulates the scientist's characteristic capacity for an anticipatory openness to scientific phenomena, an attitude ever open to possible revision upon

encountering a new phenomenon. Such a 'no' is then heuristic in function not destructive or eliminative: it describes what for Bachelard will be the enabling condition for the possibility of openness to (scientific) novelty. The scientist is thereby summoned to further innovative and creative efforts, reconstituting a new framework embracing the new experience.

Bachelard sought to go beyond phenomenology and regarded Husserl's own contributions as so many points of (dialectical) departure for Bachelard's own avowedly polemical reflections. Thus Bachelard could speak of the need for a 'phenomeno-technology' to reflect the engaged role of the human investigator and the world under investigation. Hermeneutically and phenomenologically sensitive authors have read this perspective as compatible with a hermeneutic phenomenology of (reading) scientific instrumentation.[25] But against such a tolerant syncretism of Bachelard's poetizing science and phenomenological hermeneutics of scientific culture, Bachelard's inherently antagonistic emphasis is more than clear in its original context. In the interest of and following upon the inspiration of science, Bachelard aims to *correct* phenomenology. Owing to the scientific phenomenology implicit in the doing of science, as Bachelard's philosophy of 'no', 'observation is always polemical; it either confirms or denies a prior thesis, a preexisting model, an observational protocol'. For Bachelard, philosophic reflection on science must be prepared to be instructed by science in practice. 'A truly scientific phenomenology is therefore essentially a phenomeno-technology' *(The New Scientific Spirit [6.54])*. The result of this perspective is not merely the banal pragmatism one might expect. Because Bachelard expects that the prime experience of science is to be a mathematical one, and that, as 'the mathematical tool affects the craftsman who uses it', it is not only safe to say that '*Homo mathematicus* is taking the place of *homo faber*', but that ultimately 'it is mathematics that opens new avenues to experience'. Close as this point of view is to Husserl, the gap remains and is widened by Husserl's sense of crisis, as a separation even more exacerbated by Heidegger's hermeneutic critique of technology along with the knowledge ideal of *mathesis,* or axiomatic certainty.

More negatively, resolutely committed as Bachelard was to the scientific and Enlightenment ideal disposition of a constitutional happiness or cheerfulness, Bachelard found the existentialist world-view particularly pernicious for it expressed what in his view was a false opposition between enquiring subject (poetizing poet or scientist—for they are or at least inherently can be considered the same) and world object (as created or as world to be known). Bachelard refused the distinction between the living subject and a dead or alien or meaningless world. The poetic world of human meaning was continuous with the scientific world, which for Bachelard bore the manifest imprint of the human projective imagination. Bachelard's positivism accordingly preserves the casual colloquial meaning of the word 'positive' as an optimistic outlook, or, in Bachelard's words, a 'happy' perspective. This affirmative and essentially scientistic humanism is expressed where Bachelard writes 'Science calls a world into being, not through some magic force, immanent in reality, but through a rational force immanent in the mind…. Scientific work makes rational entities real, in the full sense of the word' (*New Scientific Spirit* [6.54]).

Bachelard's work is extensively cited and has been the subject of numerous commentaries, less in the context of the philosophy of science than in principally literary

and philosophical discussions of Bachelard's poetics. Beyond anglophone continental philosophic interests, Bachelard's eclectic style of reading between literature and science has found significant hearings in France and Germany in part through the efforts of a tradition of literary theorists (as Barthes recounts). In (particularly French) history and philosophy of science, this reception is due to the influence of Bachelard's student, Georges Canguilhem, the historian of physiological science, and R.Cavailles. In this company, Michel Foucault may also be regarded as within Bachelard's intellectual sphere. But if Foucault's value may be traced to—better and more significantly, if here it can be argued that Foucault's value for science can only be understood in terms of—Bachelard's influence (cf. Tiles who prefaces her own study [6.83] by saying that her representation of Bachelard 'is a rational construct',[26] or Gutting who reads Bachelard and Canguilhem as background to Foucault, or Bhaskar who also prefers not to treat of Bachelard on his own, or on his own terms, but sets and thus inevitably defines Bachelard in opposition to Feyerabend), the question of the nature of the enduring significance of Bachelard's philosophy for the philosophy of science is more elusive. This difficulty is not a matter of the conflict between religion and modern scientific sensibility—as it was in Duhem's case—but is doubtless due to Bachelard's style. This is a style that is less esoteric than simply dated and rather specific to French literary culture, at least according to Jonathan Culler's plausible and sympathetic account. Culler implies that the lack of conceptual resonance among philosophers of science or philosophers proper in response to Bachelard's works (a limitation which is also shared by non-francophone literary theorists) is due to Bachelard's nineteenth-century style of rhetorical and imaginative reference. The style in question is one of diffuse allusion and allegory, like that of Jacques Lacan. In Culler's view, Bachelard's style is simply out of synch with current modes of expression and particularly unsuited for today's impatient styles of reading.[27] To the late twentieth-century reader's impatience may be added a fatal incapacity, that is an inability to appreciate the sense, to infer and so to understand the full value of Bachelard's allusions. An allusive, allegorical or metaphorical—in Bachelard's words *poetic*—style presumes and is necessarily dependent upon the reader's aptness for and familiarity with the conventions used.

The capacity to note such allusive resonances in Bachelard's work is essential both for readers of Bachelard's philosophy of science and for readers of his literary criticism. Accordingly, the literary theorist Ralph Smith notes that it is Bachelard's 'philosophy of science [which] must be understood in order to truly appreciate the full significance of his essays on the imagination and to assess properly his contribution to literary criticism'.[28] Where, for Bachelard, 'Science in fact creates philosophy' (*The New Scientific Spirit* [6.54]), any clear distinction between Bachelard's value for literary criticism and science must perforce be difficult to make. Still the lion's share of this attribution of value is represented by studies in literary criticism. Apart from Gutting's background reference to Bachelard's work in line with the philosophy of science, and Tiles's related discussions, Bachelard is better known for his literary contributions, in so far as Bachelard's emphasis on the imaginary continues to appeal to a distinctively French fascination with fantasy and the domains of reverie and poetic invention.

Mary McAllester Jones's recent study [6.76] employs the term 'subversive' to emphasize Bachelard's predilection for the literary and for the imagination not on the

terms of humanism but rather as 'unhinging' humanism.[29] This inverse, 'subverting' emphasis corresponds to the fashionable celebration of the postmodern but also testifies to the need to come to terms with scientism's recondite and irrecusable humanism. Citing Bachelard's claim that 'Man's being is an unfixed being. All expression unfixes him' (Bachelard in Jones [6.76], 193), Jones reads this 'unfixing' in her account of Bachelard's focus on the salutary *spiritual* value of challenge, dynamic flexibility and innovation. Thus, in Jones's expression of such an *unhinged* humanism, the movement or fluidity of articulation is paramount: 'Man is unfixed by language, not decentered' (Jones [6.76], 193).

I think it helpful to add that this openness, as a very literal flexibility, is akin to Paul Valéry's anti-Platonic celebration of the divinity that is not given negative or oblique testament, that is, not at all missed or failing, but which *speaks* precisely in our muteness in the presence of beauty.[30] Such an awe or expression of silence in the face of the beautiful rather than revealing an incapacity (such silence betrayed in the human inability to hold to a steady glance in the face of beauty proves the body's counter-divinity as Plato maintains) is the caesura, the glancing gaping that affirms and confirms, sees, sings and consecrates what is seen. In Bachelard's words with reference to Valéry, 'the temporal structure found in ambiguity can help us to intellectualize rhythms produced by sound…. We have come to realize that it is the idea that sings its song, that the complex interplay of ideas has its own particular tonality, a tonality that can call forth deep within us all a faint, soft murmuring' (*La Dialectique de la durée,* cited in Jones [6.76], p. 73). Silence thus testifies to the moving power or *dynamis* so important for Bachelard, who was of course a reader of Valéry's poetry and theory as well as a high-school teacher of chemistry and university professor of epistemology. For Bachelard's enduring aim was to show that the work of the scientist was not only comparable to that of the poet, but was in its own and full sense a poetics as well. And if, as noted, 'science creates philosophy', for Bachelard it will also be science that, most properly said and equal to any poetic discipline, creates poetry.

In the creative processes of poet and scientist, the play of thought echoes or responds to what is in each case. This is what Bachelard means by writing, 'Science calls a world into being, not through some magic force, immanent in reality, but through a rational force immanent in the mind.' And it is in this creative, reflective way that Bachelard claims that 'Science in fact creates philosophy'. But that is to say that philosophy is science reflecting on itself. The scientist is creator (poet) and philosopher, a modern Prometheus calling 'a world into being'. Here, the different senses evoked by the idea of a 'modern Prometheus' in an English literary context (Mary Shelley's *Frankenstein*) and a continental context (romanticized Titanism) are significant and testify to the difficulties inherent in assimilating such an elusive and allusive author as Bachelard.

A contemporary physicist and philosopher of science, and one who may be counted within the continental tradition, Bernard d'Espagnat, takes Bachelard's important references to Valéry a step further. For d'Espagnat, Valéry's notion of spiritual value expresses a mysticism more veiled than obvious in Valéry's contrast between spiritual and material(ist) domains. D'Espagnat suggests that the nuance to be grasped here is that between a spiritual life without God (atheist) and spiritual life of a human (here, to be fair to d'Espagnat, perhaps not necessarily a *humanist*) kind. The difference is again not

necessarily disjoint.

Yet the association with mysticism should perhaps only be emphasized in a limited way. Furthermore, for the sake of rigour, Bachelard's version of humanist scientism can be named a subversion of scientism only on the most fancifully esoteric level and that level is ambivalently problematic because of its insistent humanism. Bachelard's project must be conceived as a *subversive* humanism far more than a postmodernstyle subversion of humanism as Jones maintains. Such a subversive humanism must, it would seem, be rethought if it may not in the end be said to yield the absence of the subject. Which is of course only to say that a subversive humanism remains a humanism. This subtle humanism is such as d'Espagnat, for example, finds in Valéry. It is elusive because it entails the conjunction of mysticism and what d'Espagnat calls Valéry's 'positivism of principle'.[31] As the proponent of a mysticism which is simultaneously, coextensively in the human, the ambiguity of Valéry's position is rightfully his as poet. Bachelard's poetics of science offers an illumination of why a contemporary scientist such as d'Espagnat could turn to Valéry, a poet, as guide for 'thinking' science. Bachelard's philosophy of science represents (a position on) science as the high point of human culture (as its most profitable-productive and progressive expression). But this science-approbative perspective offers a valorization of science echoing not only Bachelard's well-rounded conservative cultural views but in uncanny resonance with the spirit of the 'two cultures' debate (and their interplay) popularized for the anglophone and traditional reader in the philosophy of science by C.P.Snow's essay *The Two Cultures*.

In Bachelard's as well as Snow's approach to the human achievement of science, science remains an ideal to be valued (and, post-Foucault, we can observe that this value is also the power of science, a power Nietzsche and Lacan would tell us which contributes to the Enlightenment role or reign of terror). Where Snow glamorizes science, Bachelard renders science a kind of poetizing and its products, its 'phenomeno-technologies', a kind of poetry. In effect, science becomes myth. But this does not resolve the opposition between *logos* and *mythos,* an opposition which has been traditional since the beginnings of Socratic philosophy. Since a glamorization of science is a part of our contemporary high-industrialist culture, Bachelard's mythification of science, as a poetizing venture, far from being a revolutionary coding (much less a double or subversive coding) only underlines the ruling mystique of science. In this supplanting of *mythos* by *logos, mythos* is not eliminated but absorbed by or subsumed under *logos*. *Mythos* becomes (is and as so named always was) a function of *logos*. With a cultural presumption exceeding Mach or Duhem, Bachelard asserts the very poetic function of science. On Bachelard's enthusiastic account, science as scientistically—which is also to say (for such is the force of the mythic-logical conversion) science as *poetically*—conceived truly *is* poetry at its best.

Bachelard's express identification of the *project* of scientific practice and method, in theory and experiment, where the scientist is taken to *constitute* the manifest entities (and not merely the image) of science (what Bachelard calls poetizing) inspired the structure of the sociological turn so decisive for the development of the new philosophy of science beyond the received hypothetico-deductive or reconstructivist view (Latour, Bloor, Woolgar). Literally constructed, the poetic project of the world of science is a suitable object for a sociology of knowledge and scientific practice or, in Bachelard's esoteric

coinage, a psychoanalysis of science.

THE HISTORY OF CONTINENTAL PHILOSOPHY OF SCIENCE

From the perspective of Anglo-American analytic-style philosophy, continental philosophy may be identified as the tradition of philosophy committed to thinking within the philosophic tradition, that is, committed to explicitly reconstituting the enduring value of the history of philosophy. For its part, analytic philosophy is not concerned with the history of philosophy although to be sure it is rooted in it. Nor is analytic philosophy, as defined by Müller and Halder, concerned with the traditional objects of philosophic inquiry such as *things* or *relations* or *events,* but rather with 'expressions, concepts, axioms, principles'.[32] On the basis of such a distinction between the objects of continental and analytic philosophic concern, Husserl's otherwise putatively realist 'To the things themselves!' articulates an interest that is not merely stylistically but constitutively antithetical to analytic philosophy.

Patrick A.Heelan characterizes continental philosophy according to two interests: '(1) its preoccupation with the problem of the 'constitution' of knowledge, and (2) the effect of the historical and cultural world context of science on the 'social constitution' of scientific knowledge'.[33] Although the word 'constitution' occurs twice in this definition, rather than focusing on the phenomenological account of such constitution, recent efforts to articulate continental philosophies of scientific theory and practice emphasize the interpretive turn to hermeneutics (Hiley, Bohman *et al.*). The hermeneutic turn is the interpretive turn taken by many analytic philosophers after Rorty, and in so far as this interpretive turn is necessarily an historical turn it is also, as mentioned above, one that is familiar to analytic philosophers of science after Kuhn. The interpretive and historic turn, which may be designated the hermeneutic turn, thus represents the most salient line of intersection between continental and analytic-style philosophy. But preliminary to any rigorous and significant expression of this intersection, as Rüdiger Bubner has demonstrated in a broader reflection on hermeneutics and critical theory, it is essential for the hermeneutic turn to be properly conceived in its technical and (that means) historical context.[34] This background critical context (and constellation of related interests) does not yet characterize the accepted path of received philosophy of science. Bubner's precision is of capital importance for the future of hermeneutic approaches to the philosophy of science. In recent historical studies of science (Hacking, Jardine, Crombie), a noteworthy attention is paid to the concept of the broadly hermeneutic rather than the specifically phenomenological philosophies of Husserl and Heidegger. Authors such as Gadamer and even Nietzsche may be invoked and references made to Ricoeur, but I think it important to consider the consequences entailed by Bubner's reservation that a genuine conversance with critical hermeneutics (in its theoretical and historical context) is often lacking.

What is more crucial than even this lack of interpretive and historical competency is the question of the advantage for the philosophy of science to be gained by taking the 'continental' turn, as it were, be that turn construed more narrowly as a historical turn or more radically as a hermeneutic turn. Would such a turn advance the fortunes of the

currently becalmed (post-Kuhnian, post-sociology of science and knowledge) philosophy of science? Long ago, Immanuel Kant observed that philosophy itself seemed almost not to progress at all if compared to the natural, formalizable or mathematical sciences. For Kant, in the first *Critique* and the *Prolegomena,* to express the difference between philosophy and science, where science shows clear signs of cumulative and accelerating development, philosophy, in contrast, appears dissolutely aporetic: without issue or advance, and without consensus, lacking even a unified perspective or standard for what would count as such advance. To date, analytic-style philosophy seeks to be true to the scientific standard for philosophic progress as implied by Kant's criticism, and seeks the kind of absolutist or cumulative understanding, including formal precision and consensus, which constitutes or at least approximates the professional mien of a scientific endeavour.

If the ideal of science remains the ideal of our modern era, and where science, echoing Kant's reference, is offered as the standard for philosophy itself, it seems patently obvious that only a *scientific* (here, analytic) project of understanding the project of science could command our interest, and analytic philosophy, given its rightful or proper distinction, should also exclude other styles as irrelevant. Thus, as we have seen, Mach, a scientist who was hence already affiliated with the (as he thought) superior thought-style, eschewed the title of philosopher. If science shows *concrete* or factual progress where philosophy manifests only moribund confusion or intestine bickering, science by contrast would appear to have the most progressive part.

But the history of science shows that even in science the idea of progress is a conceptual chestnut. As Kuhn has it, one era's idea of progress is the 'paradigmatic' error to be overthrown by the 'revolutions' of another generation. Even with a cumulative, pre-Kuhnian scheme of simple progress, the philosophy of science, failing to approximate that ideal, is more 'philosophical' (indeed to the extent of following Kant's aporetic account) than Mach's ideal science. The philosophy of science, even analytically construed, even modelled as it is on science, is still not a science as such. Nor is it a metascience: if the philosophy of science is to be a science of science, complete with *concrete* progress and visible results, it has not been very successful. Offering an array (with no end in sight) of logical accounts, analytic philosophy of science may explain and offer an understanding of the workings of science as it conceives them. It is at this formal juncture that an analogy with the practice of science must end. For where science has to do with actual events, whether theoretically construed or experimentally constituted, where science is predictive, and thus amenable to verification or refutation, where related theories and experimental tests may be expected to proliferate, the *philosophy* of science, in its project of explaining science, does not similarly test or check its explanations against the substance or 'fact' of actual science. Thus the shock of the historical, interpretive or hermeneutic, and sociological turns in the philosophy of science. Far from a critique of science as a fact, the philosophy of science begins with science as it finds it: as a fact, a given, and a given to be accepted on the scientist's own terms. Neither Mach nor Duhem would champion this perspective, precisely because of their commitment to the project of science. And Bachelard was too much a scientist himself despite his celebration of science to petrify it by treating it as an accomplished fact. Thus if the least demanding definition of the business of science as an explanation of what the world is, of the world as it is (truly, or really, or practically-pragmatically), is to 'save the

phenomena' on some level, either directly (observationally) or theoretically, the business of the philosophy of science (*qua,* pretended science of science) will need to do the same for science. But that means that the philosophy of science cannot, despite its scientistic ambitions, become a science because such an account belongs within the perspective of philosophy.

CONTINENTAL CURRENTS IN ANALYTIC-STYLE PHILOSOPHY OF SCIENCE

The concern of analytic philosophy is, as its name betrays, a concern with the logical analysis of language. Indeed, for the sake of this distinction, it should be said that analytic philosophy is committed to the dissolution (that is, literally, the analysis) of philosophic problems through their clarification. Once the traditional questions concerning things in the world, cause and effect or freedom are analysed in terms of their meaning and significance one finds that one has to do with a logical account or tractatus concerning the world (i.e., statements, claims and assertions).

The analytic tradition of the philosophy of science is marked by its attention to questions relating to the structure of scientific explanation and theory-making. If science is characterized by reciprocal theoretical and experimental activity, the philosophy of science in its analytic mode has shed more light on theory than on experiment. Conversely its disposition *vis-à-vis* experimental procedure is such that the very mention of historical studies whether by historians of science (Kuhn, Crombie) or by sociologists of science (Barnes, Shapin, Bloor, Latour, Woolgar, Knorr-Cetina) has had a disruptive effect on the analytic programme. For the analyst, historical studies are often characterized by attempts at normative historical reconstruction. Feyerabend's work offers an example of such reconstruction, where efforts to restore the sense and significance of Mach's contribution to the foundations of the philosophy of science should be seen as a logical fulfilment of Mach's appreciation of science as historically and normatively progressive.

Note that this criticism of analytic-style philosophy of science is not a complaint raised against analytic style philosophy of science from the side of continental philosophy. These criticisms have been offered in tandem with the development of the philosophy of science itself from the start, beginning with Mach and Duhem and offered as well in various styles of historical reflection by philosophers and historians of science across cultural boundaries, from Bachelard and Canguilhem to Hanson, Kuhn and Feyerabend. None of these, not excepting Bachelard and Canguilhem (or French philosophy of science today which remains as addicted to analytic as to continental approaches), may be named a typical continental philosopher.

Mach, Duhem and Bachelard along with a number of other scholars have argued that science itself is more critical, indeed more inherently 'hermeneutic', than philosophy. But this point too is problematic, and not only because of its counter-intuitive content—whereby science ends up with the virtue of being more hermeneutic than hermeneutics itself. It is overhasty to conclude as Mach for one would argue, with Duhem and Bachelard echoing him here, that scientists are the best judges of their own practice or

that science provides its own best philosophy.

Feyerabend has argued eloquently against this view in *Against Method* and his recent books. But we should not need Feyerabend's warnings that if science is not inherently a socially *responsible* enterprise, science is nevertheless neither the Moloch nor the redeemer of culture and it *is* as a practical matter of funding in fact socially *responsive*.[35] We do need to add, that for Feyerabend's programme of taking responsibility for getting 'science' to respond to social interests and needs, that if one is not to sink into the platitudes of civic virtue, now more than Nietzsche could have imagined, we desperately need a critique of critique, a critique of reason, of truth, of morality.

If the analytic philosophic perspective represents the notion that (natural and objective) science is 'mankind's most successful truth enterprise', as Heelan puts it, the continental approach rejects the Whiggish implications of this ideal. However, this is a subtle point for it must again be emphasized that today there is no approach to the philosophy of science, analytic or otherwise, which would advocate an unreconstructedly Whiggish ideal. Yet if the perspective of a continental approach to the philosophy of science is inherently problematic owing to a perception of its views as 'anti-science', read off from its explicit rejection of scientific knowledge as a 'privileged kind', the pluralism of continental philosophy recommends a reconsideration. Such a review of continental prospects for the philosophy of science is under way.

This phenomenological tradition begins with Husserl's project of grounding mathematics and physics begun in his work on arithmetic and continued in his *Logical Investigations* and *Ideas*. Related to the Husserlian tradition in turn is Merleau-Ponty's *The Primacy of Perception.* Husserl's interests grew out of the same tradition as and to that extent matched analytic philosophy (Cobb-Stevens). Considering the common origins of analytic and continental philosophy as a response (variously expressed in Husserl and Frege) to the psychologism of Meinong and Brentano, one might propose, as Michael Dummett has done, that a basic standard for bridging the continental-analytic divide should be a scholarly conversance with *both* Husserl and Frege. In this way, Hugo Dingler, a positivist and in that measure an analytic philosophic thinker, may also be productively counted as one of Husserl's students, indeed as a student who memorialized the value of his teacher's influence (Gethmann, Dingler). Recent reviews of the history of the Vienna circle point to a revaluation of the historical relationship between phenomenology and logical positivism. In line with this analytic/continental connection, Ströker, Orth, Gethmann and Haller may be read as offering comprehensive discussions of the phenomenological tradition beginning with Husserl, while Gethmann in particular stresses the development of that tradition in Lorenzen and the Erlanger school and its further development and the continuation of constructivist themes in evolutionary epistemology (Wuketis, Löw, Maturana). According to Gethmann, beyond Husserl's transcendent phenomenology, Heidegger's specific brand of hermeneutic phenomenology may be counted as a indirect influence on the development of the Erlanger school. If Foucault is included, this line of association running from Husserl to Heidegger and beyond is more obviously seen to resonate with the Edinburgh school of strong sociology of science (Rouse, Latour).

Joseph Kockelmans defends as proto-analytic the realist perspective of hermeneutic continental approaches to the philosophy of science. For Kockelmans, a hermeneutic

philosophy of science requires a 'new conception' of truth understood in Heideggerian terms as *alētheic* (truth as unconcealment), *horizonal* or, in Nietzsche's terms, *perspectival* truth (Kockelmans, Heidegger, Gadamer, Babich). But where Kockelmans's concern is meaning, his reading of truth and science is closer to a Fregean conception of *Sinn* (sense meaning) and to the traditional Diltheyan *Lebenswelt* (life-world), articulated in terms of a Gadamerian hermeneutics than to the later Heidegger's conception of truth and ambiguity.

Patrick Heelan's interest remains true to the formal constitutive (eidetic, transcendental, and genetic) phenomenology that is Husserl's project to found philosophy as a rigorous science and not just with respect to the so-called 'crisis' of his later work. Heelan's hermeneutic phenomenology expresses a realism which he calls a *horizonal realism,* articulating the basis for a phenomenology of experiment to be integrated with the theoretical expression of science. Heelan's phenomenology holds with Husserl's eidetic project the possibility of approximating the essence of a scientific object through successive profiles. The hermeneutic dimension reflects the necessity for considering the historical, social and disciplinary circumstance of the researcher. Theoretical descriptions denominate the experimental profiles that would be perceived under standard laboratory conditions and, with a hermeneutic of experimental work, become truly descriptive of what is eidetically perceived in the laboratory. Heelan's perspective accords with strong or robust realist readings of experimental science, but his is more promising than most for with a hermeneutic phenomenological expression the realist perspective becomes a matter of perception not faith.

In current English-language publications, the foremost representatives of so-called 'continental' approaches to the philosophy of science in addition to Heelan and Kockelmans include Theodore Kisiel and Thomas Seebohm. Older continental scholars seem rather more concerned with the special problems of phenomenology (intuition and formal logic, the meaning of transcendence, etc.) rather than with questions specific to the philosophy of science, while younger scholars read the value of Husserl's and Heidegger's thought with respect to science rather more historically and less theoretically. Recent studies (Gethmann, Orth, Harvey, Rouse, Crease) by contrast tend to argue for the historical influence upon rather than the current value of phenomenology and hermeneutic reconceptualizations of the expression of the philosophy of science.

In sum, this means that the work of Heelan, Kockelmans, Kisiel, Seebohm (all continental scholars, most originally of geographically continental nationality but working in the traditionally analytic academic world of United States philosophy of science), etc., must be seen as rather singular representatives of the philosophical development and application of the phenomenological and hermeneutic traditions towards an understanding of science including the natural sciences. And given the factually analytic profile of professional philosophy of science, by far the most influential contributions to the imperative value of a continental turn to historical and hermeneutic expressions of the philosophy of science must be said to have come from traditional analytic philosophers of science, complementing where not directly acknowledging the work of Heelan *et al*. This is not due to the greater perspicacity of scholars in the analytic tradition: it is only a function of its paradigmatic (and professional) dominance. Thus, for example, Hacking's recent work on statistics in *The Taming of Chance* and his recent

articles is characterized by more than a historical turn but a turn that must be properly and fully named (although Hacking does not employ the term) hermeneutic. And this same reference to hermeneutics is implicit when not explicit in many recent historical studies of science (Jardine, Crombie). What is more, in the turn to the social (in old-fashioned terms, to the *life-world*) dimensions of science inspired by the sociology of science and knowledge (Hiley *et al.,* Fuller, Latour, McMullin, Shapin/Scheffler), a new fusion of styles in the philosophy of science is emerging. If philosophy of science may not be said to be returning to its historical continental roots in all these revolutions, a review of these roots cannot but be salutary for the life of the broader discipline, for the range of styles, the plurality, of philosophies of science.

NOTES

1 The topic of the nature of a continental approach to the philosophy of science is almost necessarily esoteric rather than general. The intersection of continental thought and the philosophy of science is far from well defined in professional philosophy. Indeed, the focus on Mach, Duhem and Bachelard may even appear tendentious for these authors might well be represented as antecedent figures within traditional analytic philosophy of science. In fact they serve this antecedent function for both analytic and continental expressions of the philosophy of science. Hence the issues raised in this chapter correspond to the history of continental philosophy and the philosophy of science, their intersection, and the current state of research. As this last profile is constantly in flux, a more detailed bibliography has been included to indicate this ferment and to benefit further research.

2 R.Harré, *Philosophies of Science* (Oxford: Oxford University Press, 1976).

3 A.MacIntyre, 'Epistemological Crises, Dramatic Narrative, and the Philosophy of Science', in G.Gutting (ed.), *Paradigms and Revolutions: Appraisals and Applications of Thomas Kuhn's Philosophy of Science* (Notre Dame: University of Notre Dame Press, 1980), pp. 54–74.

4 H.Redner, *The Ends of Science* (Boulder: Westview Press, 1987).

5 K.Hübner, *Critique of Scientific Reason* (Chicago: University of Chicago Press, 1983), p. 35.

6 As a recent and comprehensive contribution to this perspective and the debate concerning it and the history of the Vienna circle as a whole in the North American context of what is by and large an American discipline, the philosophy of science, see G.Holton, 'Ernst Mach and the Fortunes of Positivism in America', *Isis,* 83:1 (1992):27–60.

7 C.Dilworth, 'Empiricism vs. Realism: High Points in the Debate during the Past 150 Years', *Studies in the History and Philosophy of Science,* 21 (3):431–62 (447).

8 P.Frank, 'Kausalgesetz und Erfahrung', *Annalen der Naturphilosophie,* 6 (1906):443–50.

9 Harré (note 1), p. 29.

10 M.Tiles [6.245], 227.

11 Blackmore cites Hans Kleinpeter's 1912 letter to Mach, reporting that 'Nietzsche read one of your essays in a scientific journal and spoke very favourably about it' ([6.8], 123). And according to Alwin Mittasch, Mach himself sent a copy of one of his articles to Nietzsche bearing the hand-written dedication 'Für Herrn Prof. Dr. Nietzsche hochachtungsvoll Ernst Mach' (Mittasch [6.151], 367). Mach's views correspond to Nietzsche's refusal to distinguish between the organic and the inorganic world as discontinuous (indeed, as opposed). For Nietzsche the living and the dead are representations of a non-discontinuous

order.

12 It goes without saying that positivism has an almost uniformly negative connotation. This negative evaluation is not unique to our own times. F.Ringer notes that in the German universities between the 1890s and the 1930s, during the Weimar period, 'the label "positivist" was almost invariably used in a deroga-tory sense' ('The Origins of Mannheim's Sociology of Knowledge', in McMullin [6.202], 55). This parallel with contemporary negative connotations of positivism extended to a critique that similarly accords with the corrective turns to the historical, the interpretive or hermeneutic and the social. For Ringer, the criticism of positivism entailed its own inherent ideology: 'positivism was seen as a kind of intellectual acid, a potentially disastrous dissolvent of wholistic concepts, traditional beliefs, and socially integrative certainties. To "overcome" the problems raised by specialization and positivism alike…there was an urgent need for a revitalization of philosophical idealism that would also reinstate *Wissenschaft* as a ground for an integral and partly normative *Weltanschauung*.'

13 I.Hacking, '"Style" for Historians and Philosophers', *Studies in the History and Philosophy of Science,* 23:1(1992):1–20 (12).

14 Berthelot, Duhem scholars seem pleased to observe, is himself today very nearly forgotten and certainly more obscure than Duhem.

15 The issue is a socially and historically complicated one. For background information on this topic, see chapter 6 of M.J.Nye [6.51]. For a fuller discussion of the particular circumstances of Hélène Duhem's efforts on behalf of her father's unpublished work, see R.N.D.Martin [6.50],

16 Parisians—and New Yorkers—will understand the profound implications of such a circumstance. Although Duhem was characterized by his Bordeaux contemporaries as testy ('violence himself'), it is not hard to imagine this perception a result of a provincial point of view.

17 Today we might understand this perspective as a reaction against *scientism,* and it is still represented by thinkers such as Jacques Ellul and René Dubos. For a discussion of the French intellectual landscape with respect to the historical features of scientific dogma and religious belief including a discussion of Dubos' situation regarded within such a vista, see H.W.Paul [6.52].

18 W.A.Wallace, *Prelude to Galileo: Essays on Medieval and Sixteenth Century Sources of Galileo's Thought* (Dordrecht: Reidel, 1981).

19 See Wallace, *Prelude to Galileo,* 'Galileo and Reasoning *Ex Suppositione*', pp. 124–59. Among others, see M.Clavelin, *The Natural Philosophy of Galileo: Essay on the Origins and Formation of Classical Mechanics* (Cambridge, Mass.: MIT Press 1974) and R.E.Butts and J.Pitt (eds), *New Perspective on Galileo* (Dordrecht: Reidel, 1978).

20 Butterfield [6.212], 27.

21 K.A.Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (New York: Harper & Row, 1963), p. 99.

22 Hacking (note 13), p. 7. Hacking feels compelled to add for reasons I dare not surmise, for Hacking does not comment on this addition, '…and also Spengler'.

23 A.MacIntyre, 'Epistemological Crises, Dramatic Narrative, and the Philosophy of Science', in Gutting (ed.) (note 3), p. 67.

24 It is hard to read Bachelard as conceiving of the scientist as a woman, hence I use masculine pronouns advisedly in what follows.

25 P.A.Heelan, 'Preface' to the English translation of Bachelard's *The New Scientific Spirit* [6.54], xiii.

26 Tiles [6.83], xv.
27 See J.Culler, *Framing the Sign: Criticism and Its Institutions* (Oxford: Blackwell, 1988). See too J.Llewellyn, *Beyond Metaphysics: The Hermeneutic Circle in Contemporary Continental Philosophy* (Atlantic Highlands: Humanities Press, 1985). This dissonant reception may also account for the recurrent fascination with Bachelard.
28 R.Smith [6.82], preface.
29 Cf. J.Derrida's discussion of the 'hinge' *(brisure)* in *Of Grammatology,* trans. G.Spivak (Baltimore: Johns Hopkins University Press, 1974), pp. 65ff.
30 Paul Valéry (1871–1945), French poet, literary theorist and essayist.
31 B.d'Espagnat, *Penser la science ou les enjeux du savoir* (Paris: Bordas, 1990), p. 223.
32 M.Müller and A.Halder, *'Analytische Philosophie', Kleines Philosophisches Wörterbuch,* (Freiburg im Breisgau: Herder, 1971), p. 19.
33 P.A.Heelan, 'Hermeneutical Phenomenology and the Philosophy of Science', in H.Silverman, *Gadamer and Hermeneutics: Science, Culture, Literature* (New York: Routledge, 1991), p. 213.
34 See for example R.Bubner [6.131] and in particular Bubner [6.132].
35 See Feyerabend [6.218, 6.219, 6.220].

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