Early Continental Philosophy of Science

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During the years leading up to and after 1890–1930, the continental conception of science had a far broader scope than the anglophone notion of science today. Even today, the German term Wissenschaft embraces not only the natural and the social sciences, including economics,\(^1\) but also the full panoply of the so-called humanities, including the theoretical study of art and theology, both important in the nineteenth century for, among other things, the formation of the life sciences.\(^2\) Philosophy itself was also counted as a science and was, in its phenomenological articulation, nothing less than the science of scientific origins or “original science” — the “Urwissenschaft” — as Martin Heidegger defined it in 1919,\(^3\) following his own intensive engagement with Edmund Husserl’s Logical Investigations.

It is also crucial for any discussion of continental philosophy of science between 1890 and 1930 to emphasize that these were, in Winston Churchill’s words, “precarious times,” times of technological and social change and of revolution, scientific and political. In a positive reflection on the transformations of

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this period, Heidegger refers, as will Husserl later, to the "crisis of philosophy as science," noting in 1925 that all "sciences and groups of sciences are undergoing a great revolution of a productive kind that has opened up new modes of questioning, new possibilities, and new horizons."4

These same critical years also saw astonishing industrial innovations, yielding many of the still-familiar achievements of modern technology, from cars (the four-wheeled automobile in 1892), airplanes (1903), and even moving sidewalks (1893); from moving pictures (1895) to public radio broadcasting (in 1922, although Marconi first transmitted a radio signal in 1895) and television broadcasting (1929). Wilhelm Röntgen took the first X-rays in 1895, while the development of modern artillery began in 1897, and Robert Goddard launched the first liquid-fueled rockets in 1926.

Continental philosophy of science has always featured reflection not only on the technologies of scientific investigation but also on human perception and technological circumspection. Louis Basso’s 1925 essay, "Induction technique et science expérimentale" was central to Gaston Bachelard’s 1928 dissertation, Essai sur la connaissance approchée, because Basso raised the question of the industrial arts as involving an inherently encompassing coordination of mechanization and technique.5 Heidegger had already emphasized in 1927 the interaction between theoretical world-disclosure and scientific research equipment, points that continue in Patrick A. Heelan’s (1926–) reflections on Werner Heisenberg’s (1901–76) physical philosophy and Heelan’s own subsequent elaboration of the phenomenology of perception as a phenomenology of laboratory discovery.6 A similar focus on the researcher’s art also characterizes Ernst


5. Basso’s “Induction technique et science expérimentale,” Revue philosophique de la France et de l’étranger 99 (1925), with its focus on the industrial arts and the relation between practical application and science along with its emphasis on technological style would be continued in Jacques Ellul and Jean Baudrillard and in still more comprehensive detail in Siegfried Giedion’s Mechanization Takes Command: A Contribution to Anonymous History (New York: Norton, 1948). An account of the historical context of the development of French philosophy of science may be found in the introduction to Anastasios Brenner and Jean Gayon (eds), French Studies in the Philosophy of Science (Frankfurt: Springer, 2009).

Mach’s (1838–1916) philosophical reflections on science and can be said to drive Ludwik Fleck’s (1896–1961) philosophical sociology of medical science.7 For his part, Heidegger’s critical reflections on science anticipate the turn to the history of science and indeed the social and historical studies of technology that increasingly inform science studies.8 Heidegger’s reflective critique of mathematics and science in his 1927 Being and Time, together with the questioning he undertakes with regard to thinking the essence of modern technology, provides the basis for his hermeneutic phenomenology of both scientific theory and practice. As he writes in the later 1930s, using what would turn out to be a timely example taken from the same experimental physics that would herald the development of the atom bomb in the mid-1940s, “Within the complex of machinery that is necessary to physics in order to carry out the smashing of the atom lies the whole of physics.”9

Heidegger’s point is echoed in the argument Heelan makes in Quantum Mechanics and Objectivity with respect to Heisenberg’s perturbation theory of measurement in his 1925–27 contributions to quantum mechanics.10 Measurement, as Heelan points out with special emphasis on the technological instruments that are used to obtain such measurements – that is, what Heidegger calls “the complex of machinery” – makes all the difference for the “new scientific spirit” – using Bachelard’s terminology – of physics.11 For Heidegger, what is at issue is the constitution of modern technological and mathematizable (measurable, calculable, model-oriented) science, conceived in both the Husserlian phenomenological sense and the mechanically explicit sense of standardized manufacture and institutional technology.12 It is thus in this sense that

8. For a discussion of science studies, see the essay by Dorothea Olkowski in The History of Continental Philosophy: Volume 8.
10. Heelan, Quantum Mechanics and Objectivity, chs 4 and 5.
the Heidegger of the 1930s describes the trajectory of modern technology as a
"humanism," much as Friedrich Nietzsche in *The Gay Science* and in his post-
humous notes characterizes mathematics and the sciences in general as what he
named, in a Kantian voice, so many modalities of "humanization."13

I. LIMIT-CONCEPTS, METHOD, AND
THE TENSIONS OF FRENCH PRAGMATISM

In his address in Paris to the 1900 World Congress of Mathematicians, David
Hilbert (1862–1943) adumbrated his famous programmatic plan for mathe-
matics, articulating his positive conviction that "However unapproachable
these problems may seem to us and however helpless we stand before them,
we have, nevertheless, the firm conviction that their solution must follow by
a finite number of purely logical processes."14 In 1930, Kurt Gödel (1906–78)
would announce the results of his own research disproving Hilbert's program
at a congress on the epistemology of the exact sciences in Königsberg at which
Hilbert himself gave the culminating public lecture of his life, publicly broadcast
on the radio, and proclaiming in conclusion "We must know – we will know."15
One did not, however, have to wait for Gödel. The crisis in the foundational
program is coterminous with Hilbert's project. It is already present in the neo-
Kantianism that dominated continental thinking on science and mathematics
in all its modalities from the empirio-criticism or environmental positivism of
Richard Avenarius (1843–96) and Mach, in the logical positivism of the Vienna
Circle that emerged from this tradition, in Henri Poincaré and Henri Bergson,
and in Husserl and Heidegger.

To the question of foundations must be added the question of method.
Heinrich Rickert's *The Limits of Concept Formation in Natural Science* (1896–
1902) distinguishes the different traditions of science as such, and Wilhelm
Dilthey (1833–1911) extends this reflection to the human sciences. Inaugur-
ating the then-influential turn to what was called Lebensphilosophie,16 Dilthey

(1902), 445.
15. Contending that there is in mathematics no "Ignorabimus," Hilbert refers to Emil du Bois-
Reymond's (1818–96) claim that there are limits to human knowledge; see Victor Vinnikov,
16. Dilthey invokes the notion of limit-concepts in *The Formation of the Historical World in the
Human Sciences*. For a 1939 account, see Carl Theodore Glock, *Wilhelm Dilheys Grundlegung
einer wissenschaftlichen Lebensphilosophie* (Berlin: Junker und Dünnhaupt, 1939). On the
social and natural sciences, see Joseph J. Kockelmans, "Science and Discipline: Some Historical
emphasized lived experience as central to the opposition between explanation and understanding. The same focus on method can be read in the reflections of social scientists such as Max Weber (1864–1920), as well as in the Existentz­philosophie of the physician turned philosopher, Karl Jaspers (1883–1969). Even Nietzsche emphasized that “the scientific spirit rests upon insight into method,” a claim that included classical philology and history as well as the physical sciences. Yet Nietzsche also argued that “the triumph of science distinguishes our 19th century less than does the triumph of scientific method over science.” Although there were clear differences between them, Nietzsche shared Mach’s emphasis on the role of error in scientific rationality along with Mach’s opposition to atomism. Indeed, one commentator’s introductory assessment of the general reaction to Mach in this context should be compared to common responses to the conjunction of Nietzsche and science: “Mach’s viewpoint provides a basis only for destructive criticism, and tends to discourage the development of hypotheses that may turn out to be fruitful.”

It is Nietzsche’s critical thinking on the sciences and on logic and mathematics, conjoined with his influence on certain scientists and mathematicians, that constitutes one of the earliest instantiations of continental philosophy of science. During the period under discussion here, Nietzsche’s critical
philosophical spirit, including his theory of eternal recurrence,\textsuperscript{22} influences not only literary and artistic traditions but also philosophical discussions of Darwinism, the debate on entropy and thermodynamics,\textsuperscript{23} and the tradition of Victorian relativity antedating Einstein, even if we set aside, for the moment, the impact of Nietzsche's thinking on Heidegger's early philosophy of science.

Highlighting Nietzsche's practical emphases together with his skepticism, the Belgian philosopher René Berthelot in 1911 coordinates American pragmatist and continental philosophy of science, comparing Nietzsche not only to the pragmatism of Charles Sanders Peirce and William James but also to Poincaré.\textsuperscript{24} Linking the American pragmatists in this way with the work of scientists is no fluke. In fact, it is difficult to parse French philosophers of science during this period without referring to Peirce and, especially, to James, who was familiar with and shared a number of interests with Bergson.\textsuperscript{25} Bergson began his intellectual life with a prize essay in mathematics, and in addition to his reflections on evolution he contributed also to the philosophy of mathematics inasmuch as he undertook the critically important step at the turn of the twentieth century of

\textsuperscript{22} For a discussion of Nietzsche's eternal recurrence, see the essay on Nietzsche by Daniel Conway in \textit{The History of Continental Philosophy: Volume 2}.

\textsuperscript{23} Drawing on Henri Poincaré's argument that a closed system of atoms must recur, in an infinitesimal approximation, to its initial state, infinitely many times, von Weizsäcker notes that Ernst "Zermelo in 1900 raised objection to the statistical interpretations of the second law of thermodynamics, the so-called Recurrence Objection" ("Nietzsche: Perceptions of Modernity," 227). This objection against entropy seemed to provide support for Nietzsche's and other theories of recurrence. For a discussion, including references to Nietzsche and Poincaré, see Stephen Brush, \textit{The Temperature of History: Phases of Science and Culture in the Nineteenth Century} (New York: Bart Franklin, 1978); more recently, Péter Erdi cites the same tradition in \textit{Complexity Explained} (Frankfurt: Springer, 2007). For an overview, including a reference to Nietzsche, see Christopher Herbert on the tradition of relativity before Einstein in \textit{Victorian Relativity: Radical Thought and Scientific Discovery} (Chicago, IL: University of Chicago Press, 2001).

\textsuperscript{24} See René Berthelot, \textit{Un Romantisme utilitaire: Etude sur le mouvement pragmatiste. 1, Le pragmatisme chez Nietzsche et chez Poincaré} (Paris: Félix Alcan, 1911). Peirce, it should be noted, was not pleased with this comparison.

\textsuperscript{25} See Henri Bergson, "On the Pragmatism of William James: Truth and Reality," Melissa McMahon (trans.), in \textit{Key Writings}, Keith Ansell-Pearson and John Mullaney (eds) (New York: Continuum, 2002) as well as Émile Boutroux's \textit{William James}, Archibald Henderson and Barbara Henderson (trans.) (New York: Longman's, Green, 1912). Horace Kallen's \textit{William James and Henri Bergson: A Study in Contrasting Theories of Life} (Chicago, IL: University of Chicago Press, 1914) begins by focusing on the perceptual contrast between, and hence affinity of, the artist and the philosopher. It should not be supposed, however, that French philosophers of the turn of the century read the American pragmatists in the way they are read today, a difference still evident, for example, in Paul Ricoeur's \textit{Freedom and Nature: The Voluntary and the Involuntary}, Erazim Kohak (trans.) (Evanston, IL: Northwestern University Press, 1966), where, in addition to a discussion of James and eidetic phenomenology, Ricoeur also compares James with Bergson and Jaspers.
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“rereading both Kant’s philosophy and Riemann’s mathematics of the manifold and gave the term *intuition* a central place in his reasoning.”

II. THE MEDIEVAL FOUNDATIONS OF MODERN SCIENCE: HISTORY OF SCIENCE AND IDEOLOGY

Contemporary analytic philosophy of science rests, implicitly or explicitly, on the crucial idea of the “scientific revolution”. In this same tradition of philosophy of science, it is well known that Pierre Duhem’s famous theoretical underdeterminism was influential for Einstein and Quine.

What is less well known is that Duhem also wrote a key account of the story of Catholic (and Islamic and Jewish) science in the Middle Ages – the ten-volume *Le Système du monde* – undermining nothing less threatening to modern science’s conception of itself (in contrast with the medieval and ancient worlds) than the very idea of the scientific revolution. Most historians and philosophers of science are hard pressed to fit the conceptual traditions of medieval science into the developmental tradition of modern science, and ancient science presents an even more difficult task.

26. Julian Rohrhuber, "Intuitions/Anschaungen," *Faits divers* 1 (2007), 2. As Jean Milet notes, in *Bergson et le calcul infinitésimal: Ou, la raison et le temps* (Paris: Presses Universitaires de France, 1974), while widely celebrated in many fields in the early part of the twentieth century, Bergson came to be denounced with rhetorically savage criticism, as some raised what Milet regards as baseless claims challenging Bergson’s mathematical proficiency. In contrast, Gaston Bachelard’s reflections on science were widely appreciated, perhaps because of his enthusiasm for subordinating “empirical diversity to the power of reason,” as Bernadette Bensaud-Vincent insightfully puts it in her discussion of Bachelard and chemistry, "Chemistry in the French Tradition of Philosophy of Science: Duhem, Meyerson, Metzger and Bachelard," *Studies in History and Philosophy of Science* Part A 36(4) (December 2005), 633.


On the subject matter of ancient science, and challenging the ongoing presumption that supposes Aristotle incapable of observation, Paul Feyerabend reminds us of the stubbornly acontextual tendencies of the Vienna Circle. In accord with Duhem's continuationist point vis-à-vis the scientific revolution, Feyerabend argues that the “Vienna Circle shares with the enlightenment an exaggerated faith in the powers of reason and an almost total ignorance concerning past achievements.” Like Nietzsche before him, Feyerabend calls for greater historical sensitivity, a hermeneutic attention to context that would increase the rigor of scientific historiography.

Duhem's 1903 discovery of themes from Leonardo's notebooks in a medieval manuscript (of one Jordanus Nemorarius) exemplifies this point. As one scholar notes, so far “from seeing Leonardo as the forerunner of modern science, Duhem fairly rooted him in the then-hitherto unexplored context of late medieval scholastic thought.” Using a metaphor borrowed from Nietzsche to speak of the Greeks' unique discoveries, Ernst Cassirer has drawn our attention to the detail of Duhem's account of “how Leonardo received a great number of problems immediately from the hands of Cusanus and how he took them up precisely at the point Cusanus had left them.” As Duhem further details, Domingo de Soto (1494–1570) had described free fall eighty years before Galileo in his 1551 commentary on Aristotle's *Physics.* Duhem's approach became the basis for an important change in the history of science. As Jeanne Peiffer explains, “Duhem exploited long-neglected sources and enlarged the body of knowledge concerned with scholastic mathematics and philosophy. He defended the thesis that, through an uninterrupted sequence of barely perceptible improvements, modern science arose from doctrines taught in the medieval schools.”

Together with a focus on interpretation and context, hermeneutic and phenomenological philosophy of science also attends to the kind of historical

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31. Here Feyerabend repudiates “the historical illiteracy of most contemporary philosophers and of their low standards of hero worship” (Science in a Free Society, 59).
32. Ibid.
specificity or perspective emphasized by Herbert Butterfield, as does Nietzsche, and later still Foucault and Georges Canguilhem.\(^{39}\) Mainstream history of science by contrast continues to tend toward "leaving things out,"\(^ {40}\) perhaps in the interest of minimizing complexity, which may be why it prefers the more neutral "presentist" to Butterfield's "whig" terminology. But the language of "presentism" exemplifies the problem of presentism. Thus Butterfield argues that:

behind the Whig interpretation – the theory that we study the past for the sake of the present – is one that is really introduced for the purpose of facilitating the abridgment of history; and its effect is to provide us with a handy rule of thumb by which we can easily discover what was important in the past, for the simple reason that, by definition, we mean what is important "from our point of view."\(^ {41}\)

**III. BEYOND PHYSICS: EXEMPLARS OF SCIENCE**

(i) Grounding physical science: geology and deep time

A relatively new science that developed in the nineteenth century, geology is a science typically neglected in mainstream discussions of the philosophy of science.\(^ {42}\) Like evolution and paleontology, geology counts as a "palaetiological" science in William Whewell's language that has had a correspondingly diverse range of influences, not least in the mid-nineteenth century via Charles Lyell's influence on Darwin.\(^ {43}\) The Scottish physicist William Thomson (1824–1907), who later became Lord Kelvin, challenged the Hytton–Lyell "uniformitarian" theory of geology\(^ {44}\) in the 1860s. Although his challenge to uniformitarian

\(^{39}\) For a discussion of Foucault and Canguilhem in this regard, see the essay by Pierre Cassou-Noguès in *The History of Continental Philosophy: Volume 4.*

\(^{40}\) Palle Yourgrau uses this expression to characterize the exclusion of Gödel from the philosophy of physics in *A World Without Time: The Forgotten Legacy of Gödel and Einstein* (New York: Basic Books, 2005), 24. See also the discussion below.


\(^{44}\) The uniformitarian theory of geology, as the name suggests, assumes the constancy of the earth's relative position in the solar system and the stability of the geological features of the earth itself over long periods of time.
theories of the age of the earth was well founded, Lord Kelvin's own simple or "elegant" mathematical model failed to represent the complex dynamics of the earth's geological evolution (and indeed its present), and hence his estimate of the age of the earth, for all its mathematical "correctness," was nonetheless erroneous. Incorporated in the second law of thermodynamics as expressed in 1865 by Rudolf Clausius (1822–88), Thomson's challenge, although not itself productive for geology per se, was enormously influential and culminated in the concept of entropy, one of the most profoundly philosophical scientific notions of the nineteenth century. This vision in turn inspired Poincaré's recurrence theorem, which stated that in a closed or bounded system all events return, infinitely many times, to their initial state, much as Nietzsche also argued with his own theory of the eternal recurrence of the same. In the spirit of "deep time," both Poincaré's and Nietzsche's articulations highlight an already-consummate past.

Beyond its nineteenth-century preludes and in addition to thermodynamics and evolution, geology saw further important innovations in the polar explorer and geologist Alfred Lothar Wegener's (1880–1930) 1912 theory of continental drift. Quintessentially revolutionary, Wegener's discovery dramatizes some of the difficulties of paradigm change, as it was ridiculed for nearly fifty years (indeed, it was still the object of ridicule by professors of earth science when this author was at university) before being finally accepted as today relevant for the sciences of ecology, evolution, and climate change. Wegener is thus a paradigmatic example for the obstacles faced by any revolutionary theory. Both for theoretical as well as contextually hermeneutic reasons, including the

development of nuclear weapons, but also given new interest in environmental philosophy, geology continues to be relevant for continental philosophy of science to this day.

(ii) Chemistry contra physics

Like the reductionist tendency to translate continental philosophy into analytic philosophy, all other sciences are thought, at least in theory, to be amenable to a translation into the terms of physics. This presupposition is inherently problematic in chemistry, even though chemistry, unlike biology or psychology, can appear to be the most physics-like of the nonphysics natural sciences. This point is exemplified by the writings of a chemist whose work is increasingly relevant in the philosophy of chemistry today, Friedrich Adolf Paneth (1887–1958).

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51. See Eric Scerri, *The Periodic Table: Its Story and its Significance* (Oxford: Oxford University Press, 2006) for a discussion of the conceptual and theoretical implications of Paneth’s work for the philosophy of chemistry. Although the discussion to follow will highlight Paneth’s work, we have already cited several chemists, notably Bachelard but also Duhem and Berthelot. To these names, Bensaud-Vincent adds Emile Meyerson (1859–1933), who began his career as a German trained chemist, and Hélène Metzger (1889–1944) ("Chemistry in the French Tradition," 634–5). For Bensaud-Vincent, the considerations of feminist philosophy and history of science are indispensable because philosophers and historians of science tend to overlook otherwise significant scientific work owing to a double prejudice against women that extends to those who lack the "prestigious diplomas" and not less (and this is the contrast as Bensaud-Vincent notes with Myerson) the crucial academic appointments that make all the difference for scholarly recognition (ibid., 644). To Metzger’s name in chemistry may be added in physics the name of Mileva Marić or Marit (1875–1948), Albert Einstein’s first wife and his mathematical and scientific collaborator, controversially listed as the coauthor of his 1905 "Zur Elektrodynamik bewegter Körper," received by the Swiss journal *Annalen der Physik* on June 30, 1905, signed Einstein-Marity. Alberto Martinez argues the mainstream view contra the significance of Mileva Marit-Einstein, but cites the Russian physicist Abram Ioffe’s 1955 account in "Handling Evidence in History: The Case of Einstein’s Wife," *School Science Review*
As a scientist, Paneth is known for his work on isotopes, collaborating in 1921 on the use of radium D as a tracer with the Hungarian chemist George de Hevesy (1885–1966). Paneth is also well known for theorizing the natural scientific limit-concept of the chemical element as such. Paneth underlines the dangers of the reductionist tradition of representing chemistry on the model of physics, writing that “As a rule, chemistry is presented by the philosophers as a science which is well on the way to transforming itself into physics, and to which, therefore, the same considerations will apply in due course.” But where Paneth sought to make these points from the perspective of the philosophy of chemistry in the 1930s, response, as Jaap van Brackel details, has been either utterly absent or glacially slow in mainstream philosophy of science. Indeed, as Joachim Schummer argues, the “one-sided picture of science tailored to physics” has often meant that analytic philosophers of science are unaware of the philosophy of chemistry in terms of the specific differences between chemistry and physics rather in the way they are generally unaware of the philosophy of biology or the philosophy of economics in spite of the important work of continental scientists and theorists such as Friedrich von Hayek and Michael Polanyi.

Duhem, himself a physical chemist, would emphasize the exceptionality of chemistry in the same way, pointing to Kant’s observation that “the theory of bodies can only become a science of nature when mathematics is applied to it.” The point of drawing a parallel with chemistry (like other sciences such as geology, as noted above) has been to underline the fact that analytic philosophers

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52. Hevesy, an independent researcher, won the Nobel Prize in Chemistry in 1943 for work that grew out of this earlier collaboration with Paneth. Michael Polanyi (1891–1976) was Hevesy’s assistant in Budapest in 1919 before returning to Germany where he had studied physical chemistry.


56. Pierre Duhem, German Science: Some Reflections on German Science and German Virtues, J. Lyon (trans.) (La Salle, IL: Open Court, 1991), 31. Duhem goes on to cite Adolphe Wurtz.
of science ignore both chemistry and the philosophy of chemistry rather than the way continental philosophy of science is similarly discounted.

But the parallel runs deeper. Paneth's own work is itself steeped in the early continental tradition of the philosophy of science. Thus Paneth's theoretical reflections on the nature of the chemical element cannot be read apart from his engagement with the epistemological reflections of Rickert's limit-concepts or the philosopher Eduard von Hartmann (1842–1906), or Meyerson's own chemical insights or Polanyi's, or of Wilhelm Wundt (1832–1920), the father of experimental psychology so important for cognitive science. Additional influences on Paneth's thinking include the theoretical insights of Hermann Weyl (1885–1955) and the physicalist and phenomenological reflections of the 1902 Nobel prize-winning chemist Emil Fischer (1852–1919).

In his "On the Epistemological Status of the Chemical Concept of Element," Paneth repudiates the reduction of chemistry to physics for the very phenomenological and critical reason that the aim of physics is ultimately to reduce "sensory qualities to quantitative determinations."57 Like Duhem, Paneth cites Kant's mathematical conventionality as justifying the exclusion of chemistry as a science. By contrast, Paneth argues that inasmuch as "chemistry is essentially non-mathematical,"58 it was the "chemist, unhampered by mathematics or indeed almost any theory, who discovered the majority of all chemical elements on the basis of the most primitive concept of substance!"59 The effectively unchanged basis of chemistry, that is, the basic schema of the periodic table itself in the wake of relativity and quantum theory, offers a corroboration, as Paneth underscores: "already in the seventies of the last century, the elements had been arranged by the chemists into a scheme, the so-called 'natural system of the elements'60 - a system thus unchanged in its character by the innovations of twentieth-century atomic theory.

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58. Ibid., 118. In a related but ultimately different point, some philosophers of science have argued that the difference between chemists and physicists can be found in the central role of the "thought experiment" in physics just where it is conspicuously absent in chemistry.
60. Scerri notes that the French geologist Alexandre-Émile Béguyer de Chancourtois (1820–86) was the first to propose a periodic arrangement of the elements according to atomic weights. Others include the English chemist John Alexander Reina Newlands (1837–98) and the German chemist Julius Lothar Meyer (1830–95) in addition to Dmitri Mendeleev (1834–1907). Mendeleev is celebrated as the first to use the table to predict elements as yet undiscovered.
Speaking here of substance as either basic (nonobservable, theoretical, or, in some philosophic expressions, constructed) or simple (observable), Paneth seeks to explain the notion of an element as such: "the whole body of chemical theory lies in the assumption that the substances which produce the phenomenon of 'simple substances' serve in the quality-less, objectively real sphere of nature as 'basic substances.'"61 Rather than progressing toward a more mathematized chemical science on the model of physics, one would do well to return to the philosophical origins of the concept of the "elemental" (and Paneth means such a return in earnest as he invokes the ancient atomists but also the Epicurean notion of "mixing"), in order to avoid the dangers of equivocation when speaking of either the permanence of substance as such or the signal chemical and even alchemical achievement that is the "creation of a new substance by mixing two known ones."62

In other words, chemical synthesis generates new compounds, and what we understand by "substance" (here regarded as much philosophically as scientifically) matters for a phenomenological understanding of such new compounds. If Paneth refers to Karl Joel's 1906 allusion to the "genesis of nature philosophy in the spirit of mysticism,"63 Bensaud-Vincent reminds us that "the challenge posed by chemistry is that its irrationals are incorporated in matter: they are everywhere, in a glass of sugared water or in the kitchen salt that we use every day."64

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62. Paneth, "The Epistemological Status," 123. Bensaud-Vincent cites Duhem's discussion of the very idea of a new chemical compound by way of his revival of the Aristotelian term "mixt" and other related concepts contra "the prevailing atomist and mechanistic views" ("Chemistry in the French Tradition," 637). Thus Duhem, in Le Mixte et la combinaison chimique, argues that in "this mixt, the elements no longer have any actual existence. They exist there only potentially because on destruction the mixt can regenerate them" (cited in Bensaud-Vincent, "Chemistry in the French Tradition," 637).


64. Bensaud-Vincent, "Chemistry in the French Tradition," 646. The distinction between physics and chemistry, a political order of rank, seems to have made all the political, theoretical difference for the scientific estimation and investigation of the first reports of cold fusion inasmuch as these reports were made by scientists who happened to be not physicists but chemists. Mainstream philosophy of science continues to regard cold fusion as an example either of pseudo-science or straightforward fraud. See Jean-Paul Biberian, "Condensed Matter Nuclear Science (Cold Fusion): An Update," International Journal of Nuclear Energy Science and Technology 3(1) (2007).
We have noted that Husserl's philosophy of science must be set into the wider scope of Hilbert's foundational program. For Husserl, this is the concern of philosophy as a rigorous science but that is only inasmuch as philosophy is concerned with truth (and not only with what is upheld as what is as good as truth). Indeed, Husserl was associated with nearly every key mathematician of the day, from Georg Cantor (1845–1918), Husserl's friend and colleague at the University of Halle between 1890 and 1910, and Gottlob Frege to Hilbert, Weyl, L. E. J. Brouwer, and Gödel. For this reason, Husserl's Philosophy of Arithmetic, which first appeared in 1891, is key to the period of continental philosophy of science under discussion. Heelan uses both Husserl's and Heidegger's reflections to develop a philosophical reflection on objectivity, particularly in Niels Bohr's and Heisenberg's theoretical interpretations, thereby suggesting that phenomenology offers an indispensable route to a clarification of quantum mechanics. Others have highlighted Einstein's role in Husserl's philosophy of science, while yet others emphasize the coordination of Poincaré with Husserl's
criticisms of logicism and formalism. Where Ryckman and Clair Ortiz Hill point to the decades Husserl spent in Halle (and the importance of Cantor), Heelan highlights, as do others, the significance of Husserl's tenure in Göttingen during the dynamic years of Hilbert's foundational program in mathematics.

Echoing René Descartes's remark in his *Discourse on Method*, Einstein famously quipped that we should attend to what scientists do, not to what they say. Richard Tieszen thus commends the value of Husserl's "philosophy of mathematics" as it bears witness to the attempt "to do justice to mathematics as it is actually given and practiced." Such a coordinated reference to the history and practice of science exemplifies both phenomenological and hermeneutic approaches to the philosophy of science, and we have seen its relevance for Nietzsche. In this spirit, Ryckman can refer to Husserl's claim to be the "true positivist," a claim that Steven Crowell likewise cites as being "only" slightly ironic.

For Descartes, as for the entire Enlightenment order of philosophizing about cognition and perception, what the mind knows is mind. Thought must be submitted to logical analysis to gain any sure knowledge of it, which leaves the gap between mind and world, thought and object. What Eugene Wigner (1902–95) would describe in a later recollection of this early period, and with patent reference to both Hilbert and Gödel, as the "unreasonable effectiveness" of mathematics in the natural sciences reflects a number of theoretically (if not to be sure "effectively" or "practically") unbridgeable chasms. While this is the traditional issue of objective versus subjective logic for both Husserl and Heidegger, Husserl's account of intentionality sidesteps just this separation insofar as the


intentional object of a presentation is the same as its actual object.” What is known by any intentional act is the intentional object or “noematic” correlate, hence the directive direction of Husserl’s classic cry: “zu den Sachen selbst” (to the things themselves).

Following the error of what Husserl calls “Galilean science” and Rickert had named “positivist” science, the worldview of modern science inaugurates the opposition between pragmaticism and realism that still stands for many as the central problem of the philosophy of science today. Modern science limits or reduces reality to its scientifically measurable, calculable, or quantifiable properties, taking reality here in the common-sense (but still counter-intuitive) meaning of scientific realism. As Husserl saw it, the technological, practical, and theoretical mathematical projects articulating the essence of modern science are fundamentally rather than incidentally opposed to one another. Galilean science (Heidegger’s calculative rationality) substitutes “the mathematically substructed world of identities for the only real world,” and in this way, so Husserl suggests, Galilean science itself comes to stand in the place of the world “that is actually given through perception … [that is,] our everyday life-world.”

The Galilean distinction between primary and secondary properties privileges the measurable as primary, so that what began as a convenience ied with Descartes to the division of subjective experience (mind) and objective world (body). And in the end, only the objective or measurable world became the real world, with the subjective and leftover worlds of “meaning” and “value,” “mind” or “spirit,” correspondingly eliminated or “reduced” to the domain of the unreal as mere phenomena. As Husserl writes in The Crisis of European Sciences and Transcendental Phenomenology, the scientific worldview “excluded in principle precisely the questions which man, given over in our unhappy times to


75. In this way, Husserl extended the concept of the life-world beyond its Romantic origins to connect the worlds of science and mathematics to the world we inhabit, a project continued in Heidegger’s philosophical reflections on the worldview of science and technology and further revitalized and ultimately radicalized in Maurice Merleau-Ponty; see Heelan’s discussion of Merleau-Ponty and Husserl in Space-Perception and the Philosophy of Science, and for a discussion of Merleau-Ponty and Derrida with respect to Husserl, see Leonard Lawlor, “The Legacy of Husserl’s ‘Urspuβ der Geometrie’: The Limits of Phenomenology in Merleau-Ponty and Derrida,” in Merleau-Ponty’s Reading of Husserl, Ted Toadvine and Lester Embree (eds) (Dordrecht: Kluwer, 2003). Florence Caeymaex also traces the connection between Merleau-Ponty and Husserl via Bergson in her Sartre, Merleau-Ponty, Bergson: Les Phénoménologies existentialistes et leur héritage bergsonien (Hildesheim: Olms, 2005).


77. Ibid., 49.
most portentous upheavals, finds the most burning: questions of the meaning or meaninglessness of the whole of this hard existence.\textsuperscript{78} The greatest threat for Husserl is thus the devaluation of consciousness, the loss of spirit or meaning.

V. HEIDEGGER: HERMENEUTIC PHENOMENOLOGY OF SCIENCE

If, as Theodore Kisiel argues, “the Husserlian approach to science is strikingly evident in the early pages of \textit{Being and Time},”\textsuperscript{79} Joseph J. Kockelmans (1923–2008) emphasizes that “in most of his publications Heidegger deals explicitly with problems which pertain specifically to the realm of philosophy of science.”\textsuperscript{80} Like Nietzsche, Heidegger argues that beyond theoretical reflection or scientific analysis, philosophy is an explicitly active questioning, especially so in the case of the philosophy of science and modern technology. It is in terms of the importance of reflection in philosophy that Heidegger argues that “all science is perhaps only a servant with respect to philosophy.”\textsuperscript{81} The critical spirit of this early account of the specific difference of philosophical reflection and scientific theorizing finds its most famous expression in the later Heidegger's provocative dictum “science does not think,”\textsuperscript{82} a claim that is already to be heard in his 1927 \textit{Being and Time}: “ontological inquiry is more primordial or original than the ontic inquiry of the positive sciences.”\textsuperscript{83}

Opposing sense-oriented reflection [Besinnung] to the calculative project of Western technologically articulated and advancing science, Heidegger varies but

\textsuperscript{78. Ibid.}
he does not alter his early discussion of the relation between science and philosophy in *Being and Time*, writing that “all scientific thought is merely a derived form of philosophical thinking.”84 With this claim, Heidegger maintains that with respect to science, philosophy “is prior in rank.”85 In *Being and Time*, this priority is characterized as a “productive logic”86 that leaps ahead “into some area of Being, discloses it for the first time, in the constitution of its Being, and, after thus arriving at the structures within it, makes these available to the positive sciences as transparent assignments for their inquiry.”87 Heidegger thus opposes the creatively foundational activity of philosophic reflection to the then popular articulations of epistemological investigations into the sciences of his era as the kind of “logic” (Heidegger sets this off in quotes) following after science, “limping along in its wake; investigating the status of [any given] science as it chances to find it in order to discover its 'method.'”88

“What is decisive” for Heidegger – who here writes in Husserl’s critical foundational spirit – in the development of mathematical physics is “the mathematical project of nature itself” inasmuch as the project “discovers in advance something constantly objectively present (matter) and opens the horizon for the scientific perspective on its quantitatively definable moments (motion, force, location, and time).”89 The “founding” of “factual science” is “possible only because the researcher understood that there are in principle no ‘bare facts,’”90 that, in other words, the material project of nature must be given in advance, *a priori*. Only then is it possible for a science to be “capable of a crisis in its basic concepts.”91

Heidegger, who remained committed to phenomenology throughout his life, emphasizes that beyond any superficially obvious call “to the things themselves,”92 phenomenology “presupposed life.”93 To understand Heidegger here requires a specific and hermeneutic attention to the biological transformation that was then under way. Including and exceeding Claude Bernard’s *milieu intérieur*, as the evolution beyond Cartesian mechanism, Heidegger’s reference was critically ecological, radically environmental: “Life is that kind of reality which is in the

90. *Ibid*.
world and indeed in such a way that it has a world. Every living creature has its environing world not as something extant next to it but as something that is there [da ist] for it as disclosed, uncovered."^94 And in 1925, Heidegger emphasized that "for a primitive animal, the world can be very simple," explaining that we run the risk of missing "the essential thing here if we don't see that the animal has a world."^95 Heidegger’s original continuum of complexity and/or simplicity must be added to contemporary readings of Heidegger’s subsequent discussions of the world-poverty of the animal in terms of indigence.

In his 1929–30 lecture course, The Fundamental Concepts of Metaphysics, Heidegger alluded to the work of Hans Driesch (1867–1941), who theorized chemical gradients in embryological development.^96 In that same course, Heidegger also invokes the theoretical biologist Jakob von Uexküll’s (1864–1944) 1909 expression of the “Umwelt,” citing the Czech biologist Emanuel Ráděl (1873–1942) on the significance of animal phototropism^97 in order to emphasize the gulf (Abgrund) between human and animal,^98 but also as a biologicist contrast to the Cartesian tendency of modern scientific biology to define both animals and human beings in mechanistic terms. This tendency remains in modern experimental biology, underlying its reliance on “models,” specifically in animal experimentation.^99 Here Heidegger reprises his hermeneutico-phenomenological case for the interpretive ontology of the human being as an animal bound to world-invention, or what Heidegger called, in an ecological modality, world-making.^^100 In this way, Heidegger had earlier cited Nietzsche’s perspectival sense of the human as the "yet to be finished animal."^101 It is in this projective, that is, yet-unfinished but to-be-finished, sense that “The world that is closest to us is one of practical concern. The environing world [Umwelt] and its objects are in space, but the space of the world is not that of geometry."^102 Historically, the mechanistic conception of life would return to triumph over the notion of “vital movement” nascent in Driesch (although it is an error to reduce Driesch’s concerns to sheer vitalism, as is evident in his emphasis on

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^94. Ibid., 163.
^95. Ibid.
^97. Ibid., 242ff., esp. 244.
^98. Ibid., 264.
electrochemical gradients), whereas Heidegger explored the living trajectory of life as opposed to its “calculable” course.103

Heidegger’s focus on life also recurs in his reference to chemistry in 1929 in order to speak of the biological and organic sciences, to underline how little is said about “the living being” when we “define it in terms of the organic as opposed to the inorganic.”104 Echoing Nietzsche’s contrastive differentiation of reductively identical kinds in chemistry,105 Heidegger reminds us to consider the example of “organic and inorganic chemistry” precisely inasmuch as “organic chemistry is anything but a science of the organic in the sense of the living being as such. It is called organic chemistry precisely because the organic in the sense of the living being remains inaccessible to it in principle.”106

Heidegger began Being and Time with a reference to the crisis in the sciences and arguing for the importance of philosophical reflection. Each particular science articulates its own regional ontology in terms of its basic constitution (Grundverfassung),107 beginning with the example of the foundational controversy of mathematics in his (and still in our own) day, “between the formalists and the intuitionists.”108 Thus Heidegger adds, in good Husserlian fashion, that what is at stake in this debate turns on “obtaining and securing the primary way of access to what are supposedly the objects”109 of mathematical science. Heidegger articulates the same foundational revolution in physics as he invokes the theory of relativity. This means that science begins with or alongside its own fundamental concepts, and inquiry into these foundations is not then a matter of scientific research, for such research is possible only on the basis of such concepts. Hence philosophical inquiry, or what Heidegger calls “ontological inquiry,” can only be “more primordial, as over against the ontical inquiry of the positive sciences.”110

For Heidegger, philosophy is, and can be, in Husserl’s terminology, the science of science not because of a venerable tradition of so regarding philosophy but

103. See Keith Ansell-Pearson, Virid Life: Perspectives on Nietzsche and the Transhuman Condition (London: Routledge, 1997) for an innovative exploration of this theme with reference to Bergson and others.
105. Nietzsche repudiates the notion that there is “nothing unchanging in chemistry” as “a scholastic prejudice. We have dragged in the unchanging, my physicist friends, deriving it from metaphysics as always. To assert that diamond, graphite, and coal are identical is to read off the facts naively from the surface. Why? Merely because no loss in substance can be shown on the scales?” (KSA, vol. 13, 374).
109. Ibid.
110. Ibid., 31. Cf. 91.
because specifically philosophical research must and “can,” as Heidegger claims, “run ahead of the positive sciences.” Thus, as Heidegger clarifies this point, the contribution of Kant’s Critique of Pure Reason “lies in what it has contributed towards the working out of what belongs to any Nature whatsoever.” Rather than epistemology, Kant’s “transcendental logic is an a priori logic for the subject matter of that region of Being called ‘Nature.’”

In this productive, disclosing sense, which Heidegger also expresses as the constitutional eventuality of alethic truth as discovery or “uncovering,” the scientist effectively opens up the truth of nature. In the alethic context of such a specifically scientific disclosure, it can be said that before “Newton’s laws were discovered, they were not ‘true.’” By way of Dasein’s “being in the truth,” the laws of Newtonian physics only first “became true.” “Newton’s laws, the principle of contradiction, any truth whatever – these are true only as long as Dasein is.”

But to say this is also to say that through “Newton the laws became true; and with them entities became accessible in themselves to Dasein. Once entities have been uncovered, they show themselves as the entities which beforehand they already were. Such uncovering is the kind of Being which belongs to ‘truth.’”

VI. GÖDEL: MATHEMATICS, TIME, AND THE COLLAPSE OF DIALOGUE

At the outset, we noted the importance of Hilbert’s 1900 program to set mathematics on the “completed” path of a science, expressed as Hilbert’s “conviction (which every mathematician shares, but which no one has as yet supported by a proof) that every definite mathematical problem must necessarily be susceptible of an exact settlement.” And we have already noted that thirty years later, Hilbert’s conviction would be proven unfounded by a young mathematician who initially thought himself to be taking up Hilbert’s program. As is already evident in the title of Gödel’s 1931 first incompleteness theorem, “On Formally Undecidable Propositions of Principia Mathematica and Related Systems, “all consistent formulations of such formal systems as number theory include

111. Ibid., 30.
112. Ibid., 31.
114. Heidegger, Being and Time, 269.
115. Ibid.
116. Ibid.
117. Ibid., translation modified.
119. Although Gödel and Hilbert never met (this is not surprising given the difference in age and, indeed, prestige), they were not unconnected given Gödel’s friendship with Hilbert’s assistant, Paul Bernays (1888–1977).
undecidable statements (unentscheidbare Sätze). As such, Gödel's incompleteness theorem undermines Hilbert's ideal of axiomatic consummation. The second incompleteness theorem states that the consistency of arithmetic cannot be proved in arithmetic itself or on its own terms, using the methods of first-order predicate calculus. As Jean Cavaillès (1903–44) has articulated Gödel's second theorem, "noncontradiction of a theory can be demonstrated only within a more powerful theory." But this means that consistency can be proven only if the formal system is inconsistent, and insofar as one needs a higher-order or more powerful system in order to prove consistency, this too falls short of the foundationalist ideal of a complete axiomatic system.

The significance of Gödel's work for mathematics and logic has been widely acknowledged. As Cavaillès notes, the "result of Gödel's work is well-known: every theory containing the arithmetic of whole numbers is necessarily non-saturated. A proposition can be asserted within them which is neither the consequence of the axioms nor in contradiction with them." Which is to say, no formal system can be both consistent and complete. And beyond his engagement with Hilbert and contributions to mathematics, there is also a case to be made for the relevance of Gödel's incompleteness theorem for Heisenberg's quantum mechanics and the most promising discussions look to John von Neumann (1903–57) and his quantum measurement theory. Yet while Gödel's contributions are readily acknowledged by many, there is significant debate in the literature regarding Gödel's philosophical accomplishments in the field of logic, and many scholars like to claim that it is easy to overstate the consequences of Gödel's incompleteness theorems.

This is noteworthy because beyond his work in mathematical logic, Gödel's ambitions were philosophical. As he wrote to the phenomenologically oriented mathematician and philosopher Gian-Carlo Rota (1932–99), "Transcendental

125. The one unifying characteristic of both popular and more recondite books on Gödel seems to be impatience with other treatments of Gödel in philosophical literature, cultural studies, and in other books on Gödel and mathematics.
philosophy ... carried through, would be nothing more nor less than Kant’s
critique of pure reason transformed into an exact science.” 126 In particular,
Gödel’s interest in time was expressed in the same Kantian spirit, as Gödel
believed, in Palle Yourgrau’s paraphrase, that “the attempt to discover what
is fundamental about our thinking about time can receive no assistance from
physics which, he argued, combines concepts without analyzing them.” 127 We
have instead to “reconstruct the original nature of our thinking.” 128

It is regrettable, but unremarkable, given the differences between Anglo­
American and continental styles of philosophizing, that throughout his life
Gödel himself would be excluded from mainstream debate on the philosoph­
ical reflections on the problems of physics and mathematical logic, and espe­
cially on the philosophy of time. Yourgrau outlines one such example in detail:
Gödel’s contribution to Paul Schilpp’s 1949 Albert Einstein: Philosopher-Scientist
was judged to be mistaken, a judgment Yourgrau argues as seemingly made “on
principle” insofar as the presumption of error was not the result of but made in
advance of debate. 129 Even in the long course of the more than half century of
scholarship to follow, Yourgrau observes, “Gödel’s contribution to the Schilpp
volume had almost no impact on the community of philosophers.” 130 In his view,
Gödel was judged to lack the credentials needed to theorize as a philosopher
and, as a consequence, Gödel’s reflective efforts were denied a proper reception,
a refusal that continues within analytic philosophy to this day. 131

The phenomenon of such academic exclusion is the common, all-too-political,
academic tendency to refuse what is not expressed in the style of the “profes­
sion”: just as Gödel failed to employ the then-current writing style of analytic
philosophy, and failed to refer to the “right” names in American analytic philos­
ophy, his own contributions to philosophy were refused access to the conversa­
tion. In this sense, Gödel stands as an example, one among many, of the closed
nature of certain domains within academic discourse and the unwillingness to
allow dissenting voices and voices coming from other traditions to have a share
in the conversation of philosophy. Sadly, this has been as true of philosophy of
science as it has been in the more “obviously” politicized discourses of social,
ethical, and political philosophy.

126. Citation in Yourgrau, A World without Time, 107.
130. Ibid.
131. Ibid., 121.