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Heidegger and Cavaillès on Crisis and the Movement of Scientific Thought

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ABSTRACT: The goal of this article is to articulate the opposed but overlapping positions of Martin Heidegger and Jean Cavaillès on the concept of a "crisis" in science, with the specific aim of emphasizing their partial agreement. The early twentieth century was rife with calls of "crisis," in which the basic foundations and standards of scientific evidence were unavoidably put into question. Perhaps the most notable of these was the "crisis of set theory," marked by the Hilbert-Brouwer controversy followed by Gödel's "incompleteness" theorems. As this article will show, based on their engagements with this particular crisis as well as their respective critiques of the history of rationalist philosophy, neither Heidegger nor Cavaillès sees the appearance of crisis as confirmation that a science has terminally run aground. They instead interpret crisis as indicative of a deeper fertility within scientific practice. This interpretation hinges on their respective understandings of the reality of science as "movement." From the standpoint of movement, the capacity to evolve and endure change is the measure for science, not the achievement of security, exactness, or technical mastery. Science for them is primarily an unpredictable and spontaneous process of experimentation and problematization.

KEYWORDS: Heidegger, Cavaillès, crisis, science

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The goal of this article is to articulate the positions of Martin Heidegger and Jean Cavaillès on the notion of a "crisis" in science. Both figures were highly influential to twentieth century continental philosophy of science and beyond, and can be seen as respectively marking the German and the French departures from Husserlian phenomenology.[1] Despite this, they have not been read together. I find this surprising given their concurrent interest in the historicity of science and scientific truth, as well as their more specific references to the twentieth century crisis of mathematics. These subjects led them to criticize the history of philosophy's ideas regarding rational evidence, with both critiques respectively culminating in rejections of Husserl's approach to the foundations of science.

While Husserl recognizes scientific thought to be historical and prone to crisis, he does so on the basis of a universal transcendental consciousness and views science, with proper methodological rigor, to be teleological and well-founded.[2] In works like *Formal and Transcendental Logic* Husserl revives the Leibnizian goal of *mathesis universalis*,[3] an ultimate logic of logics, and he even refers to the foundations of science as "complete" in the Hilbertian, set-theoretic sense.[4] In contrast, Heidegger and Cavaillès respond to the milieu of crisis by attempting to think of science as dynamic, unstable, and non-teleological, going so far as to define the reality of science as "movement." For Heidegger this movement emanates from the open and problematic structure of *Dasein*'s finitude, and Cavaillès comes to characterize this movement as internally necessary to mathematical thought itself, which he shows to be simultaneously autonomous and "incomplete."

While a larger investigation involving these three thinkers is called for, this paper will focus on Heidegger and Cavaillès. We will thus look at some of their comments on the twentieth century crisis of set theory as well as their critiques of the history of rationalist philosophy, which lead to similar rejections of traditional ideas of "evidence."

Based on these historical engagements, I hold that Heidegger and Cavaillès gesture towards a partially common characterization of the foundations of scientific thought. On one hand those foundations are "finite" and "incomplete," and on the other they are unified and generative, or productive. Such characterizations indicate that science is not a universal forward march to higher levels of security, clarity, or applicability. Science should be understood primarily as an unpredictable and spontaneous process of experimentation and problematization. By this measure, the historical occurrence of crisis takes on a creative function, inciting or indicating

a deeper fertility within scientific activity. Heidegger and Cavaillès thus reject the optimism of scientific modernism while staving off nihilistic relativism. This investigation will conclude by noting that Heidegger and Cavaillès's respective interpretations result in significantly different outlooks regarding the existential dimension of crisis, but we will primarily emphasize a mutual commitment to the unstable and fluid essence of science in general.

In the case of Heidegger, one finds an early concern towards the state of modern science, particularly logic. In the third section of *Being and Time* he points at "the controversy between the formalists and the intuitionists," that is the famous debate over logical foundations between David Hilbert and L. E. J. Brouwer.[5] For Heidegger, the crisis of set theory, which that debate was the climax of, seems like the scientific crisis *par excellence*. Despite the huge progress and exactness achieved in practice, Hilbert and Brouwer's disagreement occurred over the most basic reality of mathematical logic; over its "objects" and how to best access them. Brouwer, for instance, put the law of the excluded middle into question for the first time in centuries, on the basis that it was abused by the formalists to prove the existence of objects without a method for their actual construction. Such factionalizing intimates that a science has overstepped the limits of its most fundamental concepts, exposing their original insufficiency. Heidegger calls this a *Grundlagenkrisis*. He also references similar developments in physics and biology; that their foundations have been revealed to inadequately capture the "being" of the beings forming their respective subject matters, where "being" must of course be investigated primarily via the existential analysis of *Dasein*.[6]

Heidegger reads these crises as a culmination of the history of metaphysics, which has monopolized science since early modernity.[7] Mathematics, while it is of special interest for Heidegger, does not seem unique in practice, and mathematicians are guilty of the same methodological and metaphysical commitments as other modern scientists and philosophers. Heidegger calls their primary commitment "mathematical thinking," or "the mathematical," which he defines in works like *Being and Truth* as the underlying logic of fundamental principles that undergirds western scientificity.[8]

The logic of fundamental principles presumes a certain stable relationship between the human being and knowledge, where all rational propositional evidence reliably follows, without contradiction, from that which is self-evident or axiomatic. This notion has been the guiding thread for science

ever since Plato and Aristotle, but it was strengthened in the modern period by thinkers like Descartes and Leibniz. For instance, in Heidegger's interpretation, the primary elements of knowledge for Descartes are intuition and deduction.[9] Grounded on the fundamentum of the "I" and guided by a rigorous methodological doubt, those elements were supposedly enough to reliably grasp all that is rationally intelligible. By intuition we access the self-evident, and by deduction we lawfully proceed and gain access to everything else. For Heidegger, the presumed being of logical laws and axioms themselves hides the question of Being by conceiving a determinate closed system for what could possibly be, how it could be, and how it could be known. The "mathematical" notion of universal evidence is an effect of what he calls "Christian metaphysics," for which "reflection on what can be experienced through the senses sees itself led beyond into the super sensible."[10]

The Hilbert-Brouwer controversy has a special existential drama for Heidegger because it beautifully demonstrates the abyssal nature of *Dasein*, the inherent openness that haunts and undermines *Dasein*'s attempt to fully ground beings. With the development of set theory, mathematics seemed to be upon the verge of completing itself and solving some of its most ancient problems, but it instead found itself at the edge of an abyss with only its most basic concepts to put into question. When scientific objects and techniques become questionable in this way, it signifies that the practice itself ought to be reevaluated. For Heidegger, a scientific crisis is not just practical or technical, it is also existential. In crisis, a science finds itself asking "what am I doing?" This question runs the risk of not finding an answer, leaving the field itself groundless.

This abyssal questioning belongs to the essential, dynamic finitude of *Dasein*'s existence, which perpetually transcends or moves beyond its own understanding of itself. By our finitude we are compelled to know the world, and Being itself, through worldviews mediated by particular beings and systematic ways of being, but we are equally compelled to problematize those ways of beings in search of a more original ground. To this extent, no understanding of the world reaches an unshakeable foundation.

Heidegger might not seem particularly hopeful for the practice of science and its overarching goals, but he also claims that a profound crisis could push a scientific field into new modes of thinking:

> The real "movement" of the sciences takes place when their basic concepts undergo a more or less radical revision which is transparent

> to itself. The level which a science has reached is determined by how far it is capable of a crisis in its basic concepts. In such immanent crisis the very relationship between positively investigative inquiry and those things themselves that are under interrogation comes to a point where it begins to totter.[11]

A crisis is a self-reflective breakdown of fundamental concepts (*Grundbegriffe*); so much that a field is challenged to transform itself, along with its overall projects. From the standpoint of movement, endurance through change is the measure for science, not the achievement of exactness or technical mastery. Moreover, overcoming a *Grundlagenkrisis* has the potential to empower a science to achieve what it could not have before. This movement does not signify a traditional teleology towards completeness or universal truth. The movement of science expresses a reciprocal relation of becoming between *Dasein* and its grounding concepts. Their mutual historical becoming is part of an existential process of producing, testing, and overcoming singular ways of knowing and being in the world. This reflexive relationship is a feature of *Dasein*'s finitude; its problematic or questioning nature. That nature is abyssal and productive, making possible scientific thought while also pulling the ground from under it. The event of crisis is thus ultimately an effect of a science's historical relation to *Dasein*'s own self-reflection. It serves the simultaneous functions of threatening the being of a science while making room for its potential radical revitalization.

It is curious, given Heidegger's affirmation of the potential of crisis, that he seems to stop following the actual developments of set theory right around the late twenties. One might think that he would have paid attention to the subsequent achievements in logic with at least some interest, but by all indications it seems that he did not. His later engagements with the state of mathematics and other sciences remain implicitly engaged with the axiomatic methods that were dominant before the crisis, and his later focus moves more towards the problem of "technology" and its coopting of scientific thought.[12] This lack of engagement with logic beyond the Hilbert-Brouwer controversy marks an important difference between Heidegger and Cavaillès.

Not so different than Heidegger, Cavaillès wants to positively interpret what he calls the "unpredictable and absolute" nature of the historical movement of science, "the foundations of different types of evidence, and the links between mathematical activity as a whole and the other activities

of consciousness."[13] Unlike Heidegger though, he focuses exclusively on the critical state of contemporary mathematics, and produces a detailed history of the crisis of set theory. The first part of that history is meant to show that the question of foundations was not of chief importance until this specific crisis,[14] and the rest is dedicated to understanding the different kinds of evidence that developed during that time, as well as their modes of evolution.[15] This is so because, contra Heidegger, Cavaillès understands the primary task of mathematics to be its own transformation. His historical analysis focuses on "the continuous appearance of difficulties" within mathematical work, and this for him marks "the commencement of a theory of the common material which generates mathematical objects."[16] Advancing from this early characterization, Cavaillès builds upon his analysis in later work to suggest his conception of mathematics as a unified and independent becoming.

Cavaillès sees the greatest demonstration of the spontaneous movement of mathematics within its own work, and he is inspired by the seemingly unintentional inception of the notion of sets, as seen in the letters between Dedekind and Cantor,[17] but there were other key developments for him that only occurred after the formalist-intuitionist debates, the most significant of which is Gödel's 1931 paper, *On Formally Undecidable Propositions of Principia Mathematica and Related Systems*.[18]

The conclusion of Gödel's proofs is often understood by the following: for any effectively generated axiomatic system powerful enough to support a robust number theory, that is a system which can sufficiently support arithmetic, there are propositions that cannot be proven as either true or false; any comprehensive formal deductive system whatsoever cannot be absolutely proven to be both complete and consistent simultaneously. That implication extends beyond Russell's *Principia Mathematica* and compromises all other attempts to ground mathematical evidence absolutely. Following the intervention of Gödel, and others like Herbrand and Gentzen, the hard line between mathematics and what is called "metamathematics" crumbled, and the quest for purely axiomatic mathematical foundations was essentially given up.

Importantly, Cavaillès takes care to note that Gödel and others (Herbrand, Church, Kleene, Tarski) were still able to provide different formalizations of Peano arithmetic, Hilbertian geometry, and other branches of mathematics that had been put into question by the 1931 results, but these were mostly partial formalizations, obtained with new "model" or "computability-theoretic"

techniques of transfinite induction and general recursion.[19] Those techniques involve a reflexivity within formal concatenations (*enchaînements*) themselves which evades traditional standards of demonstrating non-contradiction by deductive-finitist means. While these developments might be seen as a relativist abandonment of old grandiose goals for pure and absolute mathematical foundations, Cavaillès sees a continuous and innovative progression within mathematics' own being. This progression is characterized by Albert Lautman, Cavaillès's famous colleague and interlocutor, as a movement from the "naïve period" to the "critical period" of mathematical logic.[20]

One of Cavaillès's main takeaways from that later group of logicians is their use of the newly deconstructed distinction between mathematics and metamathematics, which he shows in the premier case of Gödel to correspond to the relation between "founded" and "founding" aspects of a formal system. This now collapsed relation constitutes a paradoxical, that is not absolutely formalizable, but somehow still real and effective continuity between the contentual and formal aspects of rational evidence. That relation informs Cavailles's later positive and original notions of the thematic and the paradigmatic.[21] Those two features constitute the unified reality of scientific thought as movement. The movement captured by this unity cannot be "imagined," predicted, or formally represented. It is instead comprehended in a spontaneous "mathematical experience," something like Gödel's "intuition," which is radically different than Descartes's or Kant's.[22] By these notions, one views the founding and founded elements of science as different temporal perspectives of a single movement.[23] As shown by Herbrand and Gentzen's formalizations, founding and founded propositions can in fact become and produce each other at different stages within a mathematical concatenation.[24]

This shift in the standard of evidence does not threaten the being of mathematics as such, but it does change how one conceives its underlying logic as well as its overarching projects. For Cavaillès, the new awareness of the reflexive founding/founded relation suggests that scientific thought is a historical process that is essentially incomplete, but also singular, unified, and internally fertile. Moreover, this critical shift in mathematical evidence belongs to the interior movement of mathematics itself, not to the conditions of consciousness. On this line of thinking, Cavaillès moves past the transcendental a priori as the ground of mathematics, in favor of a desubjectivized "historical a priori."[25]

Despite the focus on set theory, Cavaillès makes sure to include in his analysis that this crisis arises from longstanding philosophical presuppositions. This leads to a revealing critique of the history of "mathematical philosophy," from the early moderns up to Husserl. The thinkers he engages with have different grounds for their conceptions of mathematics, but they all rely on some metaphysical apparatus or dualism that hides the life of mathematics by displacing it elsewhere.[26] Those metaphysical displacements establish stable and complete conditions for what an object or theory could be, and how they may be known. A key figure in this history is Kant, who relegated mathematical objects to the a priori synthetic fabric of spatiotemporal intuition, and concretized the act/object dualism that persists through to Hilbert, Brouwer, and Husserl alike.[27]

The upshot of this critique is that those philosophers ground mathematical evidence on something other than mathematics, and this forecloses what mathematics could be ahead of time. For Cavaillès, the continual reinvention of concepts and goals actually belongs to mathematics' nature. It is a primarily experimental science, and this makes the change and upheaval of evidence its essential project. In practice it may become subject to technical appropriation or application, and Cavaillès warns of practitioners who prioritize the safeguarding of method over the fertility of results, but he maintains that these are external and contingent limitations; not determining the necessary internal movement from one theory of evidence to another.

Here we bring to light the remarkable similarity between Cavaillès and Heidegger's historical critique of the foundations of science. Lying at the heart of recent crises is the enduring belief that scientific activity could be put on solid and "complete" logical ground. Heidegger and Cavaillès mean not only to show that such a complete ground is unattainable, but that grasping for it misses out on the true reality of science, which entails the spontaneous movement and transformation of basic concepts and methods. Similar to the problematic structure of *Dasein*'s finitude, Cavailles's history demonstrates that mathematical practice must be an ongoing experiment, constantly grounding and ungrounding itself forward. They also emphasize that this movement forward does not itself imply a stable metaphysics or teleology for truth. It is the incompletable nature of sciences like mathematics that gives them life. In light of this, it seems that the early twentieth century calls of crisis do not simply indicate the regression or impotence of scientific activity. Even for Heidegger, who never seems optimistic about

scientific practice, crisis can serve as a watershed moment that catalyzes a new approach to scientific grounds.[28]

It remains clear how Cavaillès's logic differs from Heidegger though: For Heidegger, there is a dynamic play between crisis and creation, and this is because the being of sciences like mathematics is dependent on *Dasein*'s open-problematic nature. Cavaillès, in contrast, finds the productive force of thought within mathematics itself. There is no back-and-forth relationship of grounding, between scientific thought and something else that is more primordial, but a truly autonomous being not at all determined or subordinate to the structural conditions of human existence.

In Heidegger's eyes, for example, the controversy between the formalists and intuitionists brings mathematics up against an impasse because its formerly unquestionable *Grundbegriffe*, such as the law of the excluded middle, are put into question. Such an event of ungrounding must force a new approach to mathematics as a whole; a re-grounding that either leaves behind old fundamental concepts or keeps them on in bad faith. For Cavaillès, on the other hand, the authentic practice of mathematics is not at all compromised. On his account, the law of the excluded middle is not even put into question as much as our conception of it is altered. More accurately, its specific role in mathematical practice is more genuinely illuminated, further demonstrating the independence of historically situated "mathematical experience" from universal and a priori conceptions of experience in general.[29]

For Heidegger crisis is a real, inevitable, and existential breakdown of a science's principal notions, but it is one that can strengthen it in the long run by forcing a more radical inquiry into its historically inherited ideas. This breakdown includes a real sense of danger for science. For Cavaillès, mathematical movement is so guaranteed by its incomplete nature that it is almost unimportant what constitutes a proper crisis. On this subject Cavaillès voices agreement with Hilbert's student Paul Bernays, that the crisis of set theory is basically an apparent one: "In truth, the mathematical sciences grow in complete security and harmony."[30] Mathematics for him moves forward simply by its being worked on as mathematics, whereas cries of crisis only appear externally, from a subordination of mathematical demands to those of a pregiven method, technology, or conditions of consciousness.

These differing existential positions on scientific crisis point towards deeper philosophical commitments, but I think it is clear by their

historical engagements that Heidegger and Cavaillès offer a partially common response to the atmosphere of scientific crisis that they commonly inhabited. That response is to move past attempts at completing the incompletable, and to instead embrace science as a historical unending and experimental process.

NOTES

1. Heidegger's relation to Husserl is well known but also contested. For more on Cavaillès's relation to traditional phenomenology (in English), see Knox Peden's *Spinoza Contra Phenomenology* (Stanford University Press, 2014); and Kevin Thompson's paper "Historicity and Transcendentality: Foucault, Cavaillès, and the Phenomenology of the Concept," *History and Theory* 47, no 1 (2008).
2. Edmund Husserl, *The Crisis of European Science and Transcendental Phenomenology*, trans. David Carr (Northwestern University Press, 1970).
3. Edmund Husserl, *Formal and Transcendental Logic*, trans. Dorian Cairns (Martiinus Nijhoff, 1969), 103.
4. Husserl, *Formal and Transcendental Logic*, 93–97.
5. Martin Heidegger, *Being and Time*, trans. John Macquarrie and Edward Robinson (Blackwell, 1962), 29–30.
6. Heidegger, *Being and Time*, 30.
7. Martin Heidegger, *Being and Truth*, trans. Gregory Fried and Richard Polt (Indiana University Press, 2021), 20.
8. Heidegger, *Being and Truth*, 23–29.
9. Heidegger, *Being and Truth*, 27.
10. Heidegger, *Being and Truth*, 21.
11. Heidegger, *Being and Time*, 29.
12. Martin Heidegger, *The Principle of Reason*, trans. Reginald Lilly (Indiana University Press, 1991).
13. Jean Cavaillès, *Méthode Axiomatique et Formalisme*, in *Oeuvres Complètes de Philosophie des Sciences* (Hermann, 1994). Translations mine.
14. Jean Cavaillès, *Remarques sur la Formation de la Théorie Abstraite des Ensembles*, in *Oeuvres Complètes*.
15. *Méthode Axiomatique et Formalisme* and *Sur Logique et la Théorie de la Science*, in *Oeuvres Complètes*.
16. Cavaillès, *Méthode Axiomatique et Formalisme*, 1.
17. Cavaillès translated these letters into French (in *Oeuvres Complètes*). Additionally, this dialogue is taken up at length in *Remarques sur la Formation de la Théorie Abstraite des Ensembles*.
18. Kurt Gödel, *On Formally Undecidable Propositions of Principia Mathematica and Related Systems*, trans. B. Meltzer (Dover Publications, 1992).

19. *Transfini et Continu*, in *Oeuvres Complètes*. For more, see Mathias's "The Ignorance of Bourbaki," *The Mathematical Intelligencer* 14, no. 3 (1992).
20. Albert Lautman, *Mathematics, Ideas and the Physical Real*, trans. Simon Duffy (Continuum, 2011), 141.
21. Cavaillès, *Sur Logique et la Théorie de la Science*, 27–35.
22. For more on this intuition see Burgess's "Intuitions of Three Kinds in Gödel's Views on the Continuum," in *Interpreting Gödel*, ed. Julliette Kennedy (Cambridge University Press, 2014), 11–31.
23. For more on this temporality, refer to Hare on "logical time," which he adeptly contrasts with Husserl's time consciousness in "The Effective as the Actual and the Calculable in Jean Cavaillès," *Noesis*, no 38 (2022).
24. "Indeterminacy now only exists in regard to construction: one can conceive of it as a progression of stages, each being finite in the sense specified above. There are no longer any means of grasping each step within one glance—consciousness ceases to be coextensive with its succession, [but] it is at least present in each [stage]." Cavaillès, *Méthode Axiomatique et Formalisme*, 161.
25. Cavaillès, *Sur Logique et la Théorie de la Science*.
26. Cavaillès, *Méthode Axiomatique et Formalisme*, 21–27.
27. "The object-procedure duality of action is the mask of the dialectical overtaking of one method by another, the objects posed independently of the second being the correlates of the first." Cavaillès, *Méthode Axiomatique et Formalisme*, 178.
28. It is worth noting that Heidegger's position on scientific crisis changes, particularly in *Gesamtausgabe* 65. There he seems to revoke any possibility for western science to have an authentic crisis which could unlock profoundly new possibilities.
29. "One easily sees that the narrow corselet of rules for classical logic only uncomfortably envelopes the unpredictable experiences achieved through formulas. It is them in their concrete originality that constitute objective reality, not their translation which can be reduced to a series of experiences of a different order." Cavaillès, *Méthode Axiomatique et Formalisme*, 175. Brouwer sought to impose a priori limitations on mathematical results by necessitating criteria for construction ahead of time. Hilbert's finitist method, on the other hand, held the virtue of prioritizing results over external philosophical principles, though it preserved the problematic act/object dualism in other ways. "(The law) simply expresses the dialectical independence of experience in relation to its actualization in an individual consciousness or in a given procedure." Cavaillès, *Méthode Axiomatique et Formalisme*, 180.
30. "Bernays denied in 1934—that is, shortly after the disappointment of the formalist ambitions—that there was a crisis of mathematics: "in truth, the mathematical sciences grow in complete security and harmony." [There was a] crisis only because of the extrinsic demands that were posed, partly because from the sides of both Hilbert and the intuitionists an ideal of evidence had

been defined: axiomatization and formalization were no longer moments of a creative dialectic but of obligatory uniformity." Cavaillès, *Méthode Axiomatique et Formalisme*, 181–82.

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