From:
R. Creath (ed.), Rudolf Carnap and the Legacy of Logical Empiricism,
Vienna Circle Institute Yearbook 16, DOI 10.1007/978-94-007-3929-1,

The Significance of the Hypothetical in the Natural Sciences. Ed. by Michael Heidelberger and Gregor Schiemann. Berlin: De Gruyter, 2009, ISBN 978-3-11-020694-4.

It is worth starting this review by pointing out that the word 'significance' in the title of this collected volume should be read as 'philosophical significance'. The book concerns the philosophical discussion of the hypothetical dimensions of scientific statements and theories that arose around developments in modern science from the 17th century onwards. It is well suited to those interested perhaps in the background of topics that occupied Vienna Circle participants, and of course the origins of modern philosophy of science, particularly the modern scientific realism debate, which is in some ways the more familiar theme that this book tackles through the notion of the 'hypothetical'. One article, that of Esfeld, indeed shows how this hypothetical nature can be extended to metaphysics itself through a realist account. This is quite a shift. As Bartels points out in his contribution whatever 'realism' might have meant even 50 years ago is not the realism of today. For philosophers like Duhem and Popper the easy separation we now make between the hypothetical nature of science and the question of the truth or otherwise of such hypotheses was not so apparent. Indeed one of the principal insights to emerge out of the combined works in this text is that our modern notion of science as hypothetical and its philosophical significance, cannot be historically extrapolated backwards. The interplay of hypothesis and philosophy is complex and contextual. Freudenthal in her paper on Maimonides discusses the historiographical boundaries of such accounts in this respect, which are well followed by the rest of the authors.

Schiemann contends in his paper on Heisenberg's epistemological response to the emerging physics of the 20th century, that there are really two modern distinct meanings of the notion of hypothesis. The first refers to a statement that is unverified but considered verifiable, the second to a statement that is unverifiable in principle. The major historical assertion that emerges out of this collection of articles is that it took time for the notion of natural science as hypothetical in

either of these senses to emerge and to be distinguished. Schiemann's own assertion through Heisenberg historical conception of theories is that this philosophical work was a late 19th and early 20th century project. Most of the papers act as good support for this conjecture. Rainer Sprecht for instance in his contribution on the British empiricists, reveals that the distinctions between rationalism and empiricism were only so clearly formulated after the work of Boyle and Locke, influenced as they were by Gassendi. Locke himself looked to metaphysics through the impetus of God and of man's innate nature in order to justify empiricism as naturally suited to our capacities, and reject our ability to ever access true particulate causes. Only later in the 19th and 20th centuries when the successes of science could be enrolled to support a hypothetical approach, could empiricism stand on its own feet. Snyder in her paper on British philosophy in the 19th century takes heed with the tendency amongst historians to place thinkers like Whewell and Herschel as hypothetico-deductivists, when the more contextually accurate description places them in continuity with Bacon's inductivism, much closer to Mill. Snyder identifies their inductivism with their principled belief in the necessity of inductive reasoning in the production of hypotheses. The reach of Bacon was long in this respect, and it is a mistake to ascribe modern notions of hypothesis to these actors that supposedly anticipate Popper.

The rise of hypothetical thinking hence had a different later source. It took its shape against the background of rational mechanics on the continent, and was the outcome in this respect of new thinking about the role of mathematics in physical accounts of nature. Helmut Pulte in his study of Carl Neumann's "Principles of the Galilean-Newtonian Theory "reveals the early currents of thinking that were to reconceptualise the application of mathematics as hypothetical. Neumann in this respect precedes Mach, and Poincaré. He was in turn influenced by C. G. I. Jacobi who had to some extent intuited Popper's own hypothetico-deductivist theory. As Pulte puts it, from the perspective of rational mechanics axioms were held as formal principles of organisation rather than principles with empirical content, and the whole system was held together by logical coherence rather than by 'material' truth. Jacobi according to Pulte was the first to argue that the epistemological standards applied to a formal theory of pure mathematics like number theory, should not be that applied to the mathematical-deductive system of mechanics. Neumann takes this further, moving much closer to something that looks like Popper's theory, insisting on the arbitrariness of the first principles of such a mathematical system. Successful testing itself can never justify a dogmatic attitude towards these principles. One can also see this transitional development somewhat in Hertz's own philosophical theories, but as Huettemann documents, while an important figure in the later 19th century, he shouldn't be interpreted as a stepping stone in the increasing hypothesization of science, as Boltzmann thought. Rather his work is more demonstrative of the complexities of thinking about this issue for actors at the time who didn't have this distinction. Hertz's pluralism is not easily fit in any category.

It is in fact perhaps thus no surprise that a significant portion of collection concerns Poincaré, who employs the term hypothesis extensively, and gives his own taxonomies of them. Poincaré represents a junction of various emerging themes from Hertz, Kant and others, pulling together not only underdetermination and structural realism, but also the two senses of hypotheses mentioned above. These papers examine both the content of his perspective and its proper historical situation. Heinzmann argues that despite the Kantian influences on his thinking, Poincaré is firmly non-Kantian in his belief that all types of hypotheses, whether conventional or not, are empirical. The use of word "hypothetical" to describe convention was thus not ill-chosen on his part. For Walter, Poincaré's overarching aim in promoting the hypothetical view of science, was to defend Galilean relativity, identifying his principle of physical relativity (covariance with respect to certain group formations) as the kernel of any space-time theory, Lorenzian or Galilean. Again such choices are not conventions at the outset but hypotheses that are later transformed as such. It was wrong for contemporaries of Poincaré to treat Galilean space-time as if it had been empirically disproved given the general acceptance of the Lorenzian model. Both could be fit to the available data when modifications of other physical principles were allowed. Both were hypotheses of equal standing empirically. The acceptance of the Lorenzian model had rather to be understood as a conventional choice, not as a justified truth.

Showing again the complexity of these issues when interwoven with the philosophical opinions of the context, Nordmann and Bouriau discuss the role of pragmatism in the development of concerns with the hypotheticity of science. On the pragmatic viewpoint, hypotheses are part of scientific professes that serve to generate the world. Nordmann discusses Charles Sanders Pierce engagement with the rising appreciation of the hypotheticity of science. Pierce saw his view as an antidote to the anti-realism becoming increasingly popular at the time. Bouriau raises the issue of the potential pragmatic interpretation of Poincaré when compared to the contemporaneous work of the French philosopher Vaihinger. The comparison with Vaihinger is enlightening in this respect. Both had according to Bouriau strong pragmatic elements underlying their position on the roles of theories and their relations to reality. Hypotheses were not for either to be judged or assessed simply on their truth-value, rather than their practical operation as principles for producing scientific theories. Nonetheless it seems Bouriau would come down in favour of reading Poincaré like Vaihinger, who talked of hypotheses as fictions. Hypotheses are statements about a mind-independent reality, whether true, false or unknowable. The balance of these accounts fits Poincaré within a movement for the increasing hypothetization of science and distinction between scientific statements and their truth.

This narrative that the hypothetical image of science linearly emerged from the developments of the late 19th early 20th century uniquely at least is not shared by the all the papers. McMullin argues that the treatment of science as hypothetical, albeit in an inconsistent fashion, was part of the break with Aristotelian

traditions that formed the scientific revolution and may well be its most defining element. However more modern familiar sounding notions of Boyle, who precipitated the transformation of hypothesis to something provisional or transitory must be balanced against the integration of the notion of Descartes with his own first principles philosophy and emphasis on explanatory strength. McMullin documents what might be the shifting understanding and appreciations of hypotheses through the 17th century. Newton however set aside the role of hypotheses in the *Principia*, devaluing it to the status of a query, thus setting the scene for the anti-hypothetical philosophy of rational mechanics.

The most interesting paper however is probably that from Heidelberger who discusses the philosophical position of Emile Boutroux of the latter half of the 19th century. Although Heidelberger wants to trace its influence to Poincaré, as he fairly notes it has modern resonance with the discussions on the disunity of science and the abstract nature of laws of nature. Boutroux denies the necessity of mathematical principles in nature and in turn the hierarchy of science back to physics. Sciences are rather driven by their own conceptual frameworks, making higher sciences intrinsically autonomous. Heidelberger compares his views on laws to Nancy Cartwright, but I would also mention the perspectivism of William Wimsatt as a useful comparison here too.

This consideration of Boutroux raises perhaps my main complaint about the text. This is the lack of consideration of the higher sciences, and the philosophies of its practitioners, including Whewell and Mill, who clearly had biological classification in mind in their thinking, or the British (like Darwin) and the German biologists (like Haeckel) of the 19th and early 20th century. This restricts the perspective of the book to a very traditional one, invoking what is a very traditional history of philosophy of science, to be corrected perhaps about the edges. It is one that of course puts mathematical physics at the centre of the discussion. No doubt modern philosophy of science was heavily influenced by this picture, but this just constrains the historical picture by modern concerns. In any case, theories like Boutroux's have their own modern resonance. To neglect these other perspectives on hypotheses seems to miss an opportunity to add to our knowledge of the history of philosophy of science in this respect, where the notion of hypothesis was centrally important if not more so.

This raises the other point, which is that the papers centre around questions that more broadly concern philosophy of science, like realism and instrumentalism, rather than actual practices. This puts the focus on the more refined elements again of mathematical physics, and the attendant philosophies like conventionalism that arose in particular response to it, whereas the more interesting and significant aspects of scientific practice in general are what Poincaré calls verifiable hypotheses. This would require I think a closer account of what scientists were doing and the strict methodologies they applied. Such a project would of course test whether the philosophical accounts of these mainstream figures corresponded

to what was really going on or were led by metaphysical presumptions and debates stemming from particular rarefied contexts.

Nonetheless the collection sticks to its themes well, and raises good evidence for the origins at the turn of the 20th century for the hypothetical image of science (where scientific statements and theories are considered hypotheses) and its various contingent causes. This image we now largely take for granted and project back through the history of science, yet it was far from obvious for earlier thinkers about science, and had its contingent and complex origins in the scientific developments of the late 19th and early 20th century.

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