Conventional Principles in Science: On the Foundations and Development of the Relativized A Priori.[1]

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The present volume consists of a collection of papers originally presented at the conference *Conventional Principles in Science*, held at the University of Bristol, August 2011, which featured contributions on the history and contemporary development of the notion of 'relativized a priori' principles in science, from Henri Poincaré's conventionalism to Michael Friedman's contemporary defence of the relativized a priori. In *Science and Hypothesis*, Poincaré assessed the problematic epistemic status of Euclidean geometry and Newton's laws of motion, famously arguing that each has the status of 'convention' in that their justification is neither analytic nor empirical in nature. In *The Theory of Relativity and A Priori Knowledge*, Hans Reichenbach, in light of the general theory of relativity, proposed an updated notion of the Kantian synthetic a priori to account for the dynamic inter-theoretic status of geometry and other non-empirical physical principles. Reichenbach noted that one may reject the 'necessarily true' aspect of the synthetic a priori whilst preserving the feature of being constitutive of the object of knowledge. Such constitutive principles are theory-relative, as illustrated by the privileged role of non-Euclidean geometry in general relativity theory. This idea of *relativized* a priori principles in spacetime physics has been analysed and developed at great length in the modern literature in the work of Michael Friedman, in particular the roles played by the light postulate and the equivalence principle – in special and general relativity respectively – in defining the central terms of their respective theories and connecting the abstract mathematical formalism of the theories with their empirical content. The papers in this volume guide the reader through the historical development of conventional and constitutive principles in science, from the foundational work of Poincaré, Reichenbach and others, to contemporary issues and applications of the relativized a priori concerning the notion of measurement, physical possibility, and the interpretation of scientific theories.

The first step towards the development of the relativized a priori is taken by Poincaré's modification of the Kantian epistemic categories in order to accommodate the special status of geometry. Given the construction of consistent geometric systems that negate axioms of Euclidean geometry, Poincaré notes that the Kantian idea of Euclidean geometry being necessarily true is not tenable. However, Euclidean geometry does play an important constitutive role in the physical systems in which it is employed, and in this sense retains a key feature of a prioricity. Though geometry is constitutive, it can no longer be regarded as uniquely imposed upon us since we are left with freedom to employ distinct geometries. In the first paper of the issue, 'Conventionalism, Structuralism and Neo-Kantianism in Poincaré's Philosophy of Science,' Milena Ivanova analyses the nature of Poincaré's conventionalism and its implications for his philosophy of science, in particular his neo-Kantian structuralism. Ivanova identifies three main 'conventionalist' positions associated with Poincaré's writings: conventionalism as general instrumentalist

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philosophy of science; conventionalism as a response to the underdetermination of geometry by experience; and conventionalism as an epistemic category that accounts for the status of constitutive principles in science. Ivanova argues that Poincaré's conventionalism is best understood as an epistemological thesis concerning the status of geometry, and not as a global instrumentalism, and considers the role of conventions in Poincaré's wider philosophy of science. In particular, Ivanova focuses on the Kantian aspect of Poincaré's epistemology, of which geometric conventionalism is key, and how it shapes his structuralist philosophy of science. Regarding the problem of theory change, Ivanova points at passages where Poincaré explicitly denies the arbitrariness of aesthetic values and regards values such as simplicity as regulative ideals in science. The choice between alternative geometries, then, for Poincaré whilst guided by considerations of convenience is not arbitrary and is rationally justified. Finally, Ivanova builds on Friedman's (1999) interpretation of Poincaré's views on the constitutive elements in science, seen as non-arbitrary conventions, showing how this position fits with Poincaré's overall views regarding the aim of science.

Coordinating principles are predominantly taken to function as general mediating principles connecting the mathematical formalism of a theory to the empirical data. Flavia Padovani's contribution, 'Measurement and the relativized a priori,' investigates whether the relativized a priori functions solely at the level of scientific principles, or if it also plays a more basic role in providing access to phenomena. Padovani explores Reichenbach's original thoughts on the role of constitutive principles as developed in his early work, in particular his doctoral dissertation. In this early work, Reichenbach is concerned not only with the question of coordination between abstract mathematical structure and the world via general constitutive principles, but with the more basic question of how we ascribe meaning to concepts that relate to our ability to measure what Reichenbach terms "real things". Padovani argues that the importance of Reichenbach's insight here has been overlooked in the contemporary development of the relativized a priori. For Reichenbach, coordinating principles function on different levels: (1) at the level of general scientific principles that aid to give a theory its empirical meaning, and (2) at a more basic level of individuation and measurement of physical quantities (for example, theoretical terms such as temperature become meaningful only after we have related them to specific measurement procedures). Padovani's contribution motivates the further development of how to integrate measurement procedures into a 'levelled' notion of relativized a priori. It also calls us to consider the role played by constitutive principles in theory change. While on the accepted account of relativized a priori the change of general constitutive principles implies the revision of the entire framework, coordinating measurement procedures are usually carried over to the new framework, as indicated by concept of temperature, allowing for continuity at this more basic level.

The constitutive principles in scientific theories range from the basic mathematical language used (e.g. linear algebra, calculus, geometries, manifold theories) to coordinative principles that connect the mathematical formalism to measurable physical properties for which the theories aim to account. Ryan Samaroo's contribution, 'Friedman's Thesis,' focuses on this distinction between mathematical and coordinating principles and contends that treating such principles as different in kind, with only the latter as properly constitutive, strengthens Friedman's case against Quinean epistemological holism by helping to dispel worries that purely mathematical principles and coordinative principles are on a par with regards to confirmation. The central contention of Samaroo's paper is that, contra Friedman, neither Riemannian manifolds nor the equivalence principle are properly constitutive in general relativity, insofar as they are not coordinating principles connecting physico-mathematical structure to empirical claims, but rather just part of the mathematical background of general relativity. This distinction is quite fine – Friedman holds that Riemann's theory of manifolds is constitutive of general relativity insofar as without it "the space-time structure of [general relativity] is not even *logically* possible" (Friedman 2001, p. 39; emphasis ours). Samaroo notes that this sense of constitutivity is of a different kind from that of coordinating principles, which rather than giving a logical space for scientific inquiry, play a mediating role between the mathematics and physical systems. Samaroo's 'rational reconstruction' of the formulation of general relativity highlights the coordinative role of the geodesic principle and non-coordinative roles of Riemannian manifolds and the weak equivalence principle.

The complex role played by constitutive principles in the conceivability and physical interpretation of four-dimensional spacetime in general relativity is further explored in Jonathan Everett's contribution, 'The constitutive a priori and the distinction between mathematical and physical possibility.' Everett focuses on the sense in which purely mathematical possibilities become physical possibilities in science, in particular on the Kantian aspects in Friedman's account of the development of general relativity. Everett considers the role of regulative principles in scientific progress and their relation to constitutive principles, which he argues add physical content to the theory but should not be understood as making mathematical possibilities physical. In particular, Everett argues that the rotating frame thought experiment, which plays a key role in Friedman's account of constitutivity, should rather be understood in regulative terms. Doing so, Everett promotes Cassirer's account of the development of spacetime theories in terms of regulative principles as a viable Kantian alternative to Reichenbachian constitutivity-based accounts (such as Friedman's). Everett addresses a key concern for regulativity-based accounts – that it requires an independent faculty of sensibility in order for regulative and constitutive principles to be differentiated – by focusing on Cassirer's account of objectivity. Cassirer takes objectivity to be a regulative ideal of scientific enquiry, with Everett highlighting that this can be understood in terms the invariant structure of a theory, such that science achieves greater objectivity via the broadening of symmetry groups.

The role of symmetry groups in scientific progress is the topic of the final paper of the volume. Adam Caulton's contribution, 'The role of symmetry in the interpretation of physical theories,' considers the function of symmetries in a theory and their role in how the theory is taken to represent the world. The symmetries of a theory mark the class of transformations to the theory's space of possible states under which it is preserved. Symmetries standardly present an interpretative dilemma. On the one hand, symmetries mark a redundancy in the theory in that the theory has greater mathematical structure than is required to account for the world and ought to be deemed physically insignificant, as famously debated in the Leibniz-Clarke correspondence in the case of absolute space. On the other hand, there is a non-trivial and apparently physically significant aspect of symmetries in which they appear to relate distinct physically possible states that happen to be empirically indistinguishable. Caulton argues that our understanding of which symmetries of a theory are physically significant informs the interpretation of the theory and our understanding of which symmetries play a constitutive role in the theory. Central to Caulton's analysis is the distinction between 'analytic' and 'synthetic' symmetries, loosely analogous to the distinction between analytic and synthetic propositions central to the logical empiricism of Carnap and others. Symmetries of formalism, where multiple distinct mathematical states represent a single physical state (also known as *gauge* symmetries in the literature) are labeled 'analytic' in that they are (1) 'empty' of physical content, and (2) hold independently of any contingent matters of fact (i.e. independently of the state of the world). The synthetic symmetries of a theory, conversely, are physically significant in that they hold of transformations that generate a physical difference. As such, a theory's analytic symmetries partition its state space into classes of 'physically equivalent' mathematical states. As with relativized a priori principles in general, certain symmetries can be analytic (non-physical) in the context of one theory and synthetic (physically significant) in another; for instance, the transitioning of the Galilei and Lorentz groups from synthetic to analytic symmetries are marks of scientific progress due to the recognition and elimination of surplus structure. Caulton proposes that the set of analytic symmetries ought to be maximized as much as empirical adequacy allows.

The role of conventional and constitutive principles in science continues to generate much discussion in the literature and open new questions about the epistemology and aims of science. We see in this special issue that many interpretative issues concerning the relativized a priori remain, both regarding historical episodes in the development of theories and in contemporary issues in the foundations of science. Moreover, whereas the role of relativized a priori principles in science has predominantly been analysed using case studies from fundamental physics, particularly spacetime theories, it is clear that they have a much wider role in scientific enterprise, for instance in the special sciences. We take it that the research program has much life ahead.[5]

References

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