Introduction

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I.1 The Metaphysical Foundations of Natural Science and Transcendental Philosophy

Immanuel Kant long sought to write a metaphysics of nature. In a 1765 letter to Johann Heinrich Lambert, Kant reported that he was postponing the general project he had been working on, the "Proper Method of Metaphysics." He would instead produce the paired "Metaphysical Foundations of Natural Philosophy" (*metaphysische Anfangsgründe der natürlichen Weltweisheit*) and "Metaphysical Foundations of Practical Philosophy" (*der praktischen Weltweisheit*) (Br, 10:56; see Förster 1989, 289–90) as particular examples *in concreto* of the proper philosophical methodology. Despite Kant's claim that the "content" of these projects was "already worked out," they were, in turn, deferred and subsequently shelved during his writing of the Inaugural Dissertation (MSI) and the subsequent tumult to his metaphysical outlook left in its wake. Nonetheless, Kant still harbored ambition to write a metaphysics of nature, expressing his hope to return to this project in the preface of the 1781 first edition of the *Critique of Pure Reason* while acknowledging that a critique of reason must antecede his metaphysical ambitions: "[The] **Metaphysics of Nature** . . . will be not half so extensive but will be incomparably richer in content than this critique, which had first to display the sources and conditions of its possibility, and needed to clear and level a ground that was completely overgrown" (KrV, Axxi). With the foundation for the metaphysics of nature thus laid bare with the completion of the *Critique of Pure Reason*, Kant embarked on writing the *Metaphysical Foundations of Natural Science* (*Metaphysische Anfangsgründe der Naturwissenschaft*), finally published in 1786, over twenty years after he mentioned the project to Lambert.

According to Kant, the particular metaphysics of nature discussed in the *Metaphysical Foundations of Natural Science* – that of *corporeal* nature – relates closely to the general metaphysics developed in the *Critique of Pure*

Reason. In the latter Kant situates the particular metaphysical doctrines of nature in his architectonic (KrV, A845–6/B873–4).[1] Among the subdivisions of metaphysics, in general, are the "immanent physiology of nature" alongside a "transcendent physiology" (of the world-whole and of God). The immanent physiology of nature, or what Kant elsewhere calls "the general metaphysics of nature," includes the a priori metaphysics of nature detailed especially in the body of the Transcendental Analytic. This general metaphysics of nature describes the conditions of the possibility of nature (see also B164–5, A216/B263). But there are additionally two special metaphysical doctrines of nature, the metaphysics of "corporeal nature" (rational physics) and that of "thinking nature" (rational psychology), which contain a priori knowledge concerning these more circumscribed domains. In the preface to the *Metaphysical Foundations*, Kant indicates that the particular special metaphysics of nature considered in the book is this "*metaphysics of corporeal nature*" (4:472).[2] Thus the general metaphysics of the first *Critique* lays the groundwork within which the project of the *Metaphysical Foundations* is situated – the special metaphysics of corporeal nature is one of the two chief members of the metaphysics of nature.

What is more, there is are more substantial connections between this special metaphysical doctrine and the metaphysics of the first *Critique*. As Kant states, in a special metaphysics of nature, the "transcendental principles [sc. those that make possible the concept of nature in general] are applied to the two species of objects of our senses" (MAN, 4:470). Thus, the special metaphysics of body proceeds on the tracks laid by transcendental philosophy, to wit, the framework of the categories developed in the first *Critique*. As Kant claims, the concept of matter – the empirical concept at the basis of the special metaphysics of corporeal nature (MAN, 4:469–70, 472) – is "carried through all four of the indicated functions of the concepts of the understanding (in four chapters)" (MAN, 4:476). That is, the concept is consecutively determined by the categories – quantity, quality, relation, and modality – which determination grounds the a priori principles of the special metaphysical doctrine. Along these lines, in the chapters of the *Metaphysical Foundations*, Kant, respectively, discusses matter's quantity

[1] Kant also rehearses much of this architectonic at the outset of the *Metaphysical Foundations* (MAN, 4:467).

[2] Psychology, for Kant, is impossible as a "proper natural science" – it does not adequately allow for the application of mathematics (MAN, 4:471) – meaning that its foundations are not at issue in the *Metaphysical Foundations*. This claim has been much discussed in the secondary literature, such as by Mischel (1967), Gouaux (1972), Nayak and Sotnak (1995), Sturm (2001; 2006; 2009, ch. 4), and Kraus (2016).

(Chapter 1: Metaphysical Foundations of Phoronomy), quality (Chapter 2: Metaphysical Foundations of Dynamics), relation (Chapter 3: Metaphysical Foundations of Mechanics), and modality (Chapter 4: Metaphysical Foundations of Phenomenology). Indeed, it is this dependence of the special metaphysics of corporeal nature on transcendental philosophy – the determination of the concept of matter by the categories – that guarantees its completeness (MAN, 4:474).

Furthermore, throughout the *Metaphysical Foundations* Kant utilizes principles and conceptual machinery from general metaphysics; most prominently, the principles of each of the Analogies of Experience are cited in the proofs of the corresponding mechanical laws (MAN, 4:541, 543, 544–5). In addition, Kant's theories of space and time, mathematical construction, the divisibility of objects, causality, force, and continuity all play prominent roles in the arguments of the *Metaphysical Foundations*. Altogether, such aspects demonstrate that, for Kant, the metaphysical foundations of natural science are intimately tied to and, indeed, constitute an extension of the transcendental account of nature developed in the *Critique of Pure Reason*. Yet, reciprocally, the special metaphysics of nature "does excellent and indispensable service for *general* metaphysics," insofar as it provides examples "*in concreto*" of the concepts and judgments of transcendental philosophy; that is, it "give[s] a mere form of thought sense and meaning" (MAN, 4:478). Although such claims are not immediately transparent, in all, these references both demonstrate the intimate connection between the project of the *Critique of Pure Reason* and that of the *Metaphysical Foundations of Natural Science* and depict the special metaphysics of corporeal nature as a genuine part of the critical program.

I.2 Scholarship and the Critical Guide

There is a long history of scholarship both on Kant's philosophy of science, generally, and the *Metaphysical Foundations*, in particular.[3] The keystone and starting point for modern commentaries on Kant's philosophy of science is Erich Adickes' two-volume *Kant als Naturforscher* (1924–5), a

[3] A note on versions of MAN. The *Metaphysische Anfangsgründe der Naturwissenschaft* is available in volume 4 of *Kant's Gesammelte Schriften* (1900–), originally edited by Alois Höfler and published in 1903. A new edition for the series edited by Thomas Sturm and Bernhard Thöle is forthcoming, as part of the ongoing project of publishing revised versions of the volumes constituting division I, *Werke*, of the *Gesammelte Schriften*. Konstantin Pollok also edited a free-standing German rendition that includes his substantial and valuable introduction (Kant 1997b). English translations are available from James Ellington (Kant 1970; included in Kant 1985) and Michael Friedman,

far-ranging account of Kant's philosophy of nature. Mid- to late twentieth-century accounts of Kant's philosophy of science appeared in both German – including Schäfer (1966), Hoppe (1969), Tuschling (1971), Gloy (1976) – and English scholarship – such as Buchdahl (1969b) and Brittan (1978). Furthermore, a variety of texts specifically on the *Metaphysical Foundations* were penned, including Plaass' (1965) commentary on its Preface, Butts' (1986b) edited volume celebrating the bicentennial of the book's publication, and Pollok's (2001) comprehensive commentary. Additionally, the chapters of Watkins (2001b) provide a sweeping introduction to Kant's general philosophy of science and views on a variety of special sciences.

Anglo-American scholarship has of late refocused on Kant's philosophy of science, especially spurred by the pioneering work of Michael Friedman (1992b, 2013). The recent surge of research includes special issues of journals, such as those edited by Massimi (2013), Gaukroger and Nassar (2016), Heidemann (2017), and De Bianchi and Kraus (2018), as well as assorted related interventions from individual authors, such as Edwards (2000), Watkins (2005), and Glezer (2018). Additionally, there have been many recent studies of Kant's views on particular sciences, including (but not limited to) physics,[4] chemistry,[5] psychology,[6] and biology.[7] Since the *Metaphysical Foundations* is the first and primary extension of the critical philosophy into natural science, its consideration is essential to such studies. In this volume, chapters from Sturm, Breitenbach, and Friedman are particularly relevant to Kant's general philosophy of science, especially insofar as they clarify his conception of the metaphysical foundations of natural science and situate this project with respect to the overarching critical system. Altogether the chapters of this book both clarify the general

whose version was originally in *Theoretical Writings after 1781* in the *Cambridge Edition of the Works of Immanuel Kant*, edited by Allison and Heath (Kant 2002) and later appeared as a stand-alone book in the *Cambridge Texts in the History of Philosophy* series (Kant 2004).

[4] Onnasch (2009), Warren (2010), Smith (2013), Stan (2013, 2014a, 2014b, 2015, 2016), Sutherland (2014), and Kahn (2017). Earlier relevant work includes Palter (1971, 1972), Brittan (1986), Falkenburg (1987, 1995), Carrier (1992), Watkins (1997, 1998b), Warren (2001), Pollok (2002, 2006), Emundts (2004), and Engelhard (2005).

[5] McNulty (2014, 2015, 2016, 2017, 2018), Blomme (2015), Gaukroger (2016). Earlier work concerning Kant's conception of chemistry includes Carrier (1990, 2001), Friedman (1992b, pt. 2), and Lequan (2000).

[6] Cohen (2009), Sturm (2009), Sturm and Wunderlich (2010), Dyck (2014b), Frierson (2014), and Kraus (2016, 2018). Earlier texts on psychology include Mischel (1967), Gouaux (1972), Hatfield (1990, 1992, 1995), Pa. Kitcher (1990), Makkreel (2001), and Sturm (2001, 2006).

[7] Breitenbach (2009a, 2017), Cohen (2009), van den Berg (2014), Watkins and Goy (2014), and Goy (2017). Earlier work on biology includes McLaughlin (1990), Ginsborg (2001, 2004), Zammito (2003), Quarfood (2004, 2006), and Kreines (2005).

structure of Kant's conception of natural science and open up a variety of new issues and conceptual spaces in his theory of science.

Additionally, Kant's conception of laws – particularly, of laws of nature – has been a popular, if contentious, issue in recent scholarship. A major impetus for this literature was Michela Massimi's Leverhulme Trust research project, "Kant and the Laws of Nature," which produced special issues of *Kant-Studien* (Massimi 2014a) and *The Monist* (Breitenbach and Massimi 2017), as well as the outstanding volume *Kant and Laws of Nature* (Massimi and Breitenbach 2017). A variety of scholars have also individually weighed in on the topic. Most prominently, Eric Watkins' recent *Kant on Laws* (2019) develops a comprehensive account of the unity and diversity of laws in Kant's philosophy, including an account of his views on the laws of nature, particularly those of mechanics. Many others, including Kreines (2009, 2017), McNulty (2015), Stang (2016), Breitenbach (2017), Engelhard (2018), Massimi (2014b, 2017, 2018a, 2018b), Messina (2017, 2018a, 2018b), and Patton (2017), have delved into Kant's conception of laws from various angles.[8] This is a pivotal issue in contemporary Kant scholarship, one on which the present volume has much to say. Messina and Patton's contributions to this volume both bear explicitly on the issue of laws of nature, but, insofar as the grounding of the laws of matter is at the heart of the *Metaphysical Foundations*, each of the chapters bears on this central issue.

Finally, the *Metaphysical Foundations of Natural Science* is a vexing book that inspires fascinating interpretative questions in its own right. The chapters of the present volume not only attempt to resolve some of the thorniest of these issues – such as the point and structure of Kant's Dynamics chapter (Warren) and its General Remark (McNulty), the place of the idea of absolute space in Kant's account of natural science (De Bianchi and Massimi), and his views on the mathematization of motion and its historical context (Dunlop and Stan) – but also prepare the way for future scholarship on them.

I.3 Overview of the Chapters

Chapter 1, Thomas Sturm's "Kant's Conception of the *Metaphysical Foundations of Natural Science:* Subject Matter, Method, and Aim" orients

[8] Kant's conception of laws is something of an evergreen topic, given its centrality to his metaphysics, theory of science, and account of causality. Earlier relevant literature includes Buchdahl (1971), Parsons (1984), Ph. Kitcher (1986, 1994), Guyer (1990), Thöle (1991), Friedman (1992a), Allison (1994), and Rush (2000).

the reader to Kant's project in the *Metaphysical Foundations of Natural Science* by relating it to transcendental philosophy. After carefully distinguishing various dimensions of the entanglement of the metaphysics of body and transcendental philosophy, Sturm considers accounts according to which the metaphysical foundations of natural science *complete* transcendental philosophy as well as those that posit *no* dependence of transcendental philosophy on natural science. The latter sort of interpretation especially aims to insulate the synthetic a priori transcendental philosophy from the apparent empirical disconfirmation of Kant's theory of science provided by non-Euclidean geometries, general relativistic physics, and quantum mechanics. To evaluate the two sorts of interpretation, Sturm goes back to basics and meticulously characterizes the metaphysical foundations of natural science as a doctrine in Kant's architectonic. He explains that, for Kant, sciences are essentially defined by ideas, which codify the science's ontological domain, epistemological characteristics, and axiological features. Based on a consideration of these aspects of the metaphysics of body, Sturm ultimately concludes that such metaphysics depends on transcendental philosophy, but not vice versa.

Chapter 2, "Kant's Normative Conception of Natural Science," by Angela Breitenbach, provides a fresh perspective on Kant's conception of "properly so-called natural science."[9] Notoriously, Kant espoused a particularly stringent conception of sciencehood in the preface of the *Metaphysical Foundations*, holding that only those natural sciences that are apodictically certain, contain a priori laws, and adequately allow for the application of mathematics are *properly* so-called natural science (MAN, 4:468–70). Other investigations of nature, like chemistry or empirical psychology, fail to satisfy collectively these standards and are thus deemed "improper" natural sciences. In the past, Breitenbach contends, scholars have interpreted Kant's comments on proper science either as providing a *classificatory system* for the sciences – in which chemistry is a "rational" but "improper" natural science, physics is a "proper natural science," and empirical psychology is a form of "natural description" – or as presenting Kant's *demarcation standard* – proper science is science, everything else is non- or pseudoscience. Breitenbach argues against these received interpretations, contending instead that Kant countenanced a broad conception of science that encompassed physics *along with* the "improperly so-called natural sciences." But within this broad conception of natural science,

[9] See, e.g., Plaass (1965), Watkins (1998a), Van den Berg (2011), McNulty (2014) and Zammito (2017).

the notion of proper natural science stands as a *norm* to which all sciences aspire insofar as we aim for the complete systematic unity of our knowledge. Breitenbach's "Normative Reading" of Kant's conception of natural science hence reorients our understanding of one of the most studied and notorious topics in the *Metaphysical Foundations*.

Katherine Dunlop's Chapter 3, "The Applicability of Mathematics as a Metaphysical Problem: Kant's Principles for the Construction of Concepts," is a welcome intervention into the debate surrounding Kant's account of the application of mathematics to natural science. Dunlop maintains that metaphysics' role with respect to the mathematization of nature is largely negative: it clears away obstacles to mathematization by ruling out deficient or incoherent metaphysical pictures that would make the application of mathematics impossible or unwarranted. Thus, Kant dismisses monadology, for making impossible the application of mathematics; Newtonian absolute space, for incoherence; *physica generalis* (a Wolffian approach to cosmology popular in eighteenth-century Germany), for simply *assuming* the application of mathematics to nature, instead of explaining it; and Lambert's empiricist account of matter, for not grounding a priori knowledge of outer objects. Ultimately, according to Dunlop, it is only the analysis of matter as an object of possible experience that provides the desired a priori foundations making possible mathematical construction. However, the determination of the *specific* constructions utilized in natural science is a task for which metaphysics is not liable; metaphysics' responsibilities end with its validation of the mere possibility of mathematical construction.

Chapter 4, "Phoronomy: Space, Construction, and Mathematizing Motion," by Marius Stan, innovates on the slim literature on the Phoronomy by concentrating on basic questions and Kant's historical context. Stan first examines what phoronomy, as a doctrine, really *is*, for Kant: he concludes that it is a "kinematics for particle collision in a force-free vacuum," instead of a theory of dynamics or a general doctrine of bodies. Stan proceeds to explicate Kant's concept of speed and situate it with respect to notions utilized in mechanics of Kant's day, arguing that Kant espoused a "pre-classical concept" of motion, which allowed for the sort of geometric representation of motions that he aspired toward. Finally, Stan examines Kant's proof of the parallelogram law, which codifies the method for combining motions as *directed* quantities.[10] According to Stan,

[10] The parallelogram law of motions states, roughly, that the composition of two motions is represented by the diagonal of the parallelogram produced by the lines representing the two composed motions.

there remains an open problem for Kant's phoronomy: namely that, despite the claimed synthetic apriority of the parallelogram law, it involves empirical information. Specifically, the concepts of relative space and motion as well as the principle of Galilean relativity are all empirical. Thus, Stan concludes the chapter with a challenge to exegesis of the Phoronomy chapter: How can its proposition be synthetic a priori, when its sources are empirical?

Chapters 5 and 6, by James Messina and Lydia Patton, respectively, utilize the *Metaphysical Foundations of Natural Science* in order to push the recently burgeoning debates on Kant's conception of natural laws in new and fruitful directions. In his "Space, Pure Intuition, and Laws in the *Metaphysical Foundations*," Messina examines how the pure intuition of space relates to the laws of nature. This issue arises because of some conflicting and enigmatic comments that Kant makes about the dependence of physical laws on space throughout the critical decade. On the one hand, in the Dynamics of the *Metaphysical Foundations*, Kant suggests that the laws of diffusion of the fundamental attractive and repulsive forces – those essential to matter's filling of space – admit of a *purely* geometrical derivation. On the other hand, these laws must involve *some* empirical content, and, in the *Prolegomena*, Kant appears to deny that the pure intuition of space can ground laws of outer nature. Messina contends that global features of space and time play a critical, ineliminable role in grounding the modal force of Kant's laws of physics, and his chapter thus constitutes a careful, discerning corrective to accounts of laws that ground their necessity wholly on the categories. Furthermore, by elaborating this essential role for the pure form of intuition vis-à-vis Kant's laws of nature, Messina's chapter also contributes to our understanding of the relation between natural science and transcendental philosophy.

In her "Finitism in the *Metaphysical Foundations*," Lydia Patton aims at a novel articulation and extension of the recently popular necessitarian interpretation of Kant's account of laws and, more particularly, of her own version of this approach (Patton 2017). Patton especially examines the relation between natures, which serve as the basis for the necessity of empirical laws of nature according to a necessitarian account, and the purported completeness of Kant's system of nature. Examining this relation gives rise to her "Finitist Account of Laws," according to which the system of nature outlined in the *Metaphysical Foundations* is finitist in the sense that Kant eschews appeal to actual infinities, both at the level of content (no actually infinite concepts) and at the level of demonstrations (proof in Kant's system depends on concrete, intuitive mathematical

constructions). According to Patton, Kant's finitism and necessitarianism interact reciprocally with one another: on the one hand, Kant's finitist proofs need refer only to natures of material bodies, whereas, on the other hand, such natures must not involve any actual infinities. Patton's chapter points in a new direction for literature on Kant's conception of laws and brings this topic into an important dialogue with that of the completeness of his system of nature.

Chapters 7 and 8 concern foundational questions regarding the second chapter of the *Metaphysical Foundations* – the Dynamics – and the associated conception of matter. Warren's "The Construction of the Concept of Space-Filling: Kant's Approach and Intentions in the Dynamics Chapter of the *Metaphysical Foundations*," answers a devilishly straightforward question: What is the aim of the Dynamics chapter? Warren's detailed and resourceful answer provides a new and fruitful framework for understanding the Dynamics chapter. Central to Warren's concerns is the notion of mathematical construction in relation to Kant's dynamical theory of matter. First, Warren provides a helpful account of the possibility of such mathematical construction, despite certain apparent conceptual obstacles. Subsequently, Warren particularly digs into the mathematical laws of the dynamical theory of matter, particularly, the force laws governing the diffusion of the fundamental attractive and repulsive forces. Warren traces these laws to the "universal law of dynamics," according to which the intensity of a force stands in inverse ratio to the space upon which it acts, building on his prior work on the Dynamics (Warren 2017). Warren explains that a bulk of the Dynamics is oriented toward demonstrating that the fundamental forces of matter – those of attraction and repulsion – satisfy the conditions of the universal law of dynamics. By dint of the applicability of this law to the fundamental forces, they are thereby in-principle mathematically constructible. Warren, like Dunlop in her chapter, emphasizes that metaphysics plays a preparatory role vis-à-vis mathematization, accounting for its possibility, but that it is not responsible for the specifics of the mathematization.

McNulty's Chapter 8, "Beyond the Metaphysical Foundations of Natural Science: Empirical Physics and the General Remark to the Dynamics," examines the enigmatic appendix to the Dynamics chapter, the General Remark to the Dynamics, in which Kant discusses both his preferred, force-based approach to natural explanation and a slate of empirically variable material phenomena – such as density, cohesion, and elasticity – that constitute the "specific variety of matter." McNulty seeks to understand the precise relation between the phenomena canvassed in

the Remark and the synthetic a priori theory of matter developed in the body of the *Metaphysical Foundations*. He argues that, for Kant, the specific variety of matter is to be explained by appeal to the fundamental forces of matter; density, cohesion, and elasticity are understood as emerging from the complex interplay of the fundamental attractive and repulsive forces. However, such explanations require the postulation of different sorts of matter expressing the fundamental forces to distinct degrees. In particular, Kant's account of cohesion rests upon the assumption of an everywhere present ether, whose repulsive force totally outstrips its attraction. McNulty's chapter thus clarifies both the relation between the Remark and the body of the *Metaphysical Foundations* and how Kant uses the fundamental forces of matter to explain empirical phenomena.

Chapters 9 and 10 by Silvia De Bianchi and Michela Massimi, respectively, concern the final chapter of Kant's *Metaphysical Foundations of Natural Science*, the Phenomenology, which concerns possible, actual, and necessary motions. Both authors find the faculty of reason and its characteristic *ideas* – postulated concepts corresponding to objects beyond the possibility of experience – lurking behind the scenes of the Phenomenology, and both chapters also situate the Phenomenology historically: De Bianchi's, especially with respect to Euler, and Massimi's, especially with respect to Kant's pre-critical corpus. In her "How Do We Transform Appearance into Experience? Kant's Metaphysical Foundations of Phenomenology," Chapter 9, De Bianchi centers on the "reduction" of all motion to absolute space, an idea of reason. As she understands it, such reduction achieves the greatest end of reason in rational physics, namely, the systematic unification of all relative motions, which transforms them into genuine experiences. Although De Bianchi thus highlights the essential role of absolute space with respect to the Phenomenology, she notes a discrepancy between the functions of space and time. Absolute *time*, as an idea of reason, does not play a role in the Phenomenology; the process of unification, rather, makes possible the *actual* measurement of time via the relations among co-moving reference frames. De Bianchi finds support for this reading in the account of measurement from the *Critique of the Power of Judgment*, bringing together passages rarely read in conjunction.

In Massimi's Chapter 10, "Absolute Space as a Necessary Idea: Reading Kant's Phenomenology through Perspectival Lenses," examines Kant's prima facie peculiar claim that the idea of absolute space is "necessary, not as a concept of an actual object, but rather as an idea, which is to serve as a rule for considering all motion therein merely as relative"