Transcendental Idealism and its Influence on Nineteenth Century Science

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In this chapter we motivate and introduce the doctrine of transcendental idealism as expounded by Immanuel Kant (§1), the general theory of matter (§2) and principle of natural purpose (§3) that he took it to ground, as well as the influence of transcendental idealism, via its various philosophical (re-)interpretations (§4), on some of the more important conceptual developments in mathematical physics and in the life sciences over the course of nineteenth century (§§5–6).

1 Kant's Transcendental Idealism

During the middle decades of the 1700s, Kant had been occupied with the question of how to make metaphysics—whose aim as he conceived it was to provide us with rationally certain cognition of things as they exist in themselves—legitimate, in the sense that his goal was to provide metaphysics with a principled methodological grounding (Kant 1755, 1:387, Kant 1763a, 2:66, Kant 1763b, 2:285). By the time of his *Inaugural Dissertation* (1770), Kant had settled on two basic principles. The first was a kind of generalised principle of causality through which one explains, a priori, how substances mutually interact (Kant, 1770, §16). The other was the *principle of reduction* (ibid., §25). Given that the goal of metaphysics is rationally certain cognition of the 'intelligible world' of things as they exist irrespective of how we happen to be able to apprehend them (ibid., §4), the principle of reduction instructs us that the objects of metaphysics should not be conceived to include or in any way depend upon anything that refers to sensation, not even to space and time: the mere forms, according to Kant, through which our sensible representations are apprehended as ordered (ibid., §13–15).

Although Kant was still hopeful, in 1770, that progress could be made in metaphysics in this way, by the time of the writing of the *Critique of Pure Reason* (or first *Critique*) in 1781, he no longer believed this to be true.[1] Instead he became convinced of the doctrine

[1]Kant had become convinced of this at least as early as 1772 (see his letter to Marcus Herz (Zweig, 1967, p. 75)). The period between the publication of his *Inaugural Dissertation* and first *Critique*, during which he published nothing of substance, is commonly referred to as Kant's 'silent decade'.

he was to call *transcendental idealism* (A26–28/B42–44),[2] which declares that cognition of the intelligible world is, for us, impossible, and that cognition, for us, must be understood to be relative to the sensible conditions under which we, as rational subjects, are able to apprehend an object. Since our cognition is *discursive* (Allison, 2004, 11–19) in the sense that to know an object is to subsume our intuition of it under some concept; and since intuitions of external objects are mediated by our *faculty of sensibility*, while concepts arise from the spontaneous activity of our *faculty of understanding*, this entails that cognition requires the contribution of both (A51/B75). Metaphysical cognition, which must not refer to experience in any way, is therefore not possible for us.

If such cognition were possible, then besides analytic knowledge, obtained from unpacking (in the sense of the logic of Kant's time) what is entailed by a given concept, it would also include synthetic knowledge, wherein two or more distinct concepts are cognised as necessarily connected in some way. When Kant declares metaphysical cognition (which is, by hypothesis, a priori) to be impossible what he really means is synthetic cognition. There is, however, another kind of synthetic a priori knowledge that is not metaphysical. This is our knowledge of mathematics, most vividly illustrated by geometry. Simply analytically unpacking the concepts of a straight line, an angle, and the number three, according to Kant, will not allow us to cognise how the sum of a triangle's angles, for example, are related to a right angle. But by *constructing* a triangle via spatial intuition in accordance with Euclid's postulates, we can understand how the various aspects of that figure necessarily relate to one another (A715-717/B743-745).

Kant's goal in the first *Critique* is to explain how synthetic a priori knowledge is possible in general and to investigate its limits (B19). In both cases the answer is provided by *possible experience*. The forms of possible experience are known a priori, and since it is through these forms that appearances are represented as ordered (A20–A22/B34–36), the kind of knowledge they yield is synthetic knowledge. Possible experience is also the limit of this kind of cognition insofar as it is only in reference to it that synthetic a priori cognition may be obtained. While traditional metaphysics will be disappointed by this, such cognition is far from trivial, and in the first part of the first *Critique*, Kant lays out a basic conceptual framework with which to characterise it.

The experience of an object considered as such, according to Kant, is comprised of two distinct aspects: the intuition, mediated by sensibility, through which the object appears to us, and the concept of the understanding whereby we combine the various intuitions of it under a given rule. The two forms through which objects appear are space and time, associated with outer and inner sense, through which we intuit external objects and our own mental states, respectively (A22/B37). These forms are *pure*—Kant also calls them pure intuitions—since they refer to the form of an appearance as such rather than to what is actually given in sensation (A20/B34–B35). Similarly, pure concepts are forms of thought (A51/B75). In *transcendental logic*, which unlike general logic does not abstract completely away from the content of cognition, these pure forms are called the *categories*: of *Quantity* (*unity*, *plurality*, *allness*), of *Quality* (*reality*, *negation*, *limitation*), of *Relation* (*inherence*, *causality*, *community*), and of *Modality* (*possibility*, *existence*, *necessity*) (A80/B106); they correspond to the logical forms of judging (A79/B105) in relation to objects which can be given to us in intuition (A62/B87).

Besides the categories, which apply to a given object of experience, the understanding provides us with *synthetic a priori principles* (A159-235/B198-294) for what can be an

[2] I have followed the common convention to prefix page numbers from the first and second editions of the first *Critique* with 'A' and 'B', respectively.

object of experience at all, which we uncover when we consider the rules, or *schemata*, which govern the way that the categories are applied (A137–147/B176–187). This use is either mathematical or dynamical, the former relating to the intuition itself through which an object appears, and the latter to the existence of an appearance as such (A160/B199). According to the *mathematical principles*: the *Axioms of intuition* and *Anticipations of perception*, the appearance of a thing must be apprehended as having a determine extension (A163/B204) and a particular degree of intensity (A166/B208). These are *constitutive* for appearances insofar as they tell us what an appearance must be like if it is to exist for us at all. The *dynamical principles*: the *Analogies of experience* and the *Postulates of empirical thought as such*, are *regulative* for appearances; they connect given appearances together in time and thus presuppose that these have already been apprehended. According to the *Analogies of experience*, all changes in time presuppose a permanent substance as their basis (A182–183/B225–226), they occur in accordance with the law of cause and effect (A189/B232), and all substances perceived to be simultaneous in space are mutually interacting (A211/B256). The *Postulates of empirical thought as such* tell us (A218/B265–266) that our conception of a given object must either cohere with the formal conditions for an experience in general (as a merely possible object), be related (as an actual object) via the analogies of experience to some actual perception, or else its coherence with some perception must be understood to follow necessarily from the universal conditions of experience.

The third faculty involved in cognition is the faculty of *reason*, through which we draw connections between the understanding's concepts. Although reason is merely regulative for experience, through an unavoidable illusion brought about by the nature of our cognitive power (A295/B352), its principles appear to us as constitutive for the existence of objects in general. But with the illusions of reason exposed and the contradictions that follow from them avoided, the way becomes clear for a reconceptualisation of traditional metaphysics, in the fully general sense, as a system of methodological principles for the investigation of nature (A643–668/B671–696).

2 Kant's Metaphysical Foundations of Natural Science

Natural science, in the proper sense, according to Kant, considers its objects entirely from the point of view of a priori principles, as opposed to the descriptions of mere empirical regularities one finds in an improperly so-called natural science. The former is also called pure, the latter applied, natural science (Kant, 1786, 4). The pure part of any science (whether the science as a whole is pure or not) divides into its mathematical part and its metaphysical part. The former is concerned with what is constructible in intuition given a mathematical representation of an object. The latter contains the principles relating to the existence of such a thing. They further divide into principles that make nature, in general, possible at all, and principles relating to particular natures, i.e., particular kinds of things; where the most general distinction one can make, in the latter case, is between corporeal and thinking nature (ibid., 5). Empirical psychology, which pertains to thinking nature, is not a proper natural science, according to Kant; since mathematics is not applicable to it, it can only be a historical doctrine. Therefore only a doctrine of corporeal nature can be a natural science in the proper sense, from which it follows that we can identify the metaphysical principles of natural science with the metaphysical principles for the possibility of matter, i.e., the matter of appearance, in general (ibid., 7–8).

These are divisible into four groups, corresponding to our use of the four groups of

categories in relation to an object in *motion*, which is the only way that we can represent an object as affecting our senses (ibid., 12). The pure doctrine that considers motion with respect to the categories of quantity is called *phoronomy*. Phoronomy governs the composition of motions considered as such, i.e., considered as nothing other than the change, in the outer relations of a movable thing to a given space (ibid., 17), that is described solely in terms of their respective speeds and directions (ibid., 15). To determine the motion resulting from the composition of two given (rectilinear) motions of a single point in a given space,[3] phoronomy dictates that we represent the first of these motions against the backdrop of absolute space, which in itself is nothing other than an abstract representation of any larger space we might imagine the space the movable is situated in, i.e., its relative space, to be moving through (ibid., 16). The second is represented as a motion of the movable's relative space in the direction opposite to it but with the same speed. For instance, consider a given point that is being moved simultaneously, with equal speeds, to the right and to the left. To determine the resulting composite motion we (a) represent the first motion (which is to the right) as a motion through absolute space. We then (b) represent the point's relative space as also moving to the right, i.e., in the opposite direction of the second motion. Since, in this case, both motions have identical speeds, it follows that the point will not change its position with respect to its relative space. We can use a similar construction to determine the result of composing two motions (not necessarily of the same speed) in the same direction, or whose directions are related by some arbitrary angle (ibid., 26–28), and so on.

The pure doctrine corresponding to the categories of quality is called *dynamics*. Dynamics, which presupposes phoronomy, governs how matter comes to fill or be moved out of a given space (ibid., 33–34). This is accomplished through attractive and repulsive (ibid., 35) *moving forces* (ibid., 62). Repulsive forces, in particular those associated with each of the parts of a given, infinitely divisible (ibid., 40) matter, determine the (continuously variable) degree to which that matter fills a space (ibid., 36). Attractive force is prior to repulsive force insofar as it is the ground upon which we say that something is able to fill a space at all, and thus the ground upon which we can conceive of two given movables as being in contact. Since it is logically prior to contact, its action must, according to Kant, be conceived of as independent of contact, and thus independent of whether or not the space between two given matters is filled; i.e., attractive forces act immediately at a distance on other matters, beyond their surface of contact, and in principle through empty space (if such were to exist) (ibid., 50).[4]

The doctrine corresponding to the categories of relation is called *mechanics*; it presupposes both phoronomy and dynamics insofar as it represents matter as such as something movable with moving force; and it considers how matters so represented communicate their motion to one another (ibid., 75). The *quantity of matter* (in the mechanical sense) in a given space is simply the aggregate of the movables in it (ibid., 76, 78). When these all move together with the same speed and in the same direction they exert their collective moving force externally as a *mass*. A given quantity of matter acting in mass at a given speed yields a quantity of motion (ibid., 76–77) through which the given quantity of matter manifests itself in experience (ibid., 79), thus providing the only means through which to estimate it (ibid., 76). Besides this, mechanics dictates that in any change of a corporeal nature, the total quantity of matter will neither be diminished nor increase (ibid., 80), that any such change must be due to an external cause (ibid., 82), and that action and reac-

[3] We will come back to the question of non-rectilinear, i.e., circular, motions at the end of this section.

[4] Kant's doctrine does not require the existence of empty space (Kant, 1786, 62).

tion must be equal to one another in every case of a communication of motion between movables (ibid., 84).

Finally, the doctrine corresponding to the categories of modality is called *phenomenology*. It presupposes the doctrines of phoronomy, dynamics, and mechanics and determines the modality, with respect to each, through which a given motion may be represented as the motion of an object (ibid., 93–94). Phoronomical principles determine which motions of the object are possible. In particular, given the rectilinear motion of a point relative to some space, it makes no difference, objectively, whether one represents that point as moving and the space as stationary, or vice versa (ibid., 94). Dynamical principles serve to determine which motions of the object are actual. In particular, circular motion (as opposed to rectilinear motion), since it requires a continuously acting force, is, according to Kant, a manifestation of the original moving forces of matter (ibid., 96–97). The principles of mechanics, finally, determine which motions of the object are necessary insofar as they determine the necessary relations that obtain between movables, in particular according to the law of equal action and reaction (ibid., 97).

3 Kant's Critique of Teleological Judgement

In the first *Critique*, Kant's primary concern had been to determine the conditions for the possibility of theoretical cognition. This, as we saw in Section 1, is the exclusive domain of the faculty of understanding. As for the faculty of reason, although theoretical cognition is not possible for it, it nevertheless has a practical use. This was the concern of Kant's second *Critique* (1788), the mature basis of his moral philosophy, which need not concern us further here. The concern of Kant's third and final *Critique*, the other of Kant's works which was to have an enormous impact on nineteenth century science, was *judgement*, the mediating link between understanding and reason (Kant, 1790, 177). Judgement in general is the ability to subsume a given particular under some universal rule or concept. Whenever the latter is also given (by the understanding), then the power of judgement *determines* the particular in accordance with that rule. Otherwise judgement has to *reflect* on the empirical regularities that characterise the particular to find, for itself, a universal rule from which they can be seen to necessarily follow (ibid., 179). And in some cases judgement has no choice but to reflect upon the empirical regularities that it finds in nature as if they were part of a purposively designed unified system (ibid., 180–181).

Purposiveness in general can be thought of as either formal or real (i.e., material). The former is characteristic of geometry. Geometrical figures, and the objective and universal principles through which they are constructible, are useful for many purposes. But insofar as these principles merely describe constraints on what can be a possible experience for us, we are not entitled to regard them as themselves actually based on a purpose (ibid., 364). By contrast, when it comes to actually existing material things, there are cases—which Kant calls *natural purposes*—in which we are not only entitled but required to regard them as based on a purpose that is real (ibid.).

A natural purpose, like a work of art, is such that it can only be conceived of in a lawlike way if the existence of all of its various parts, as well as their relations to one another, are understood to be based upon the idea of the thing as a whole (ibid., 366–367, 373). Unlike a work of art, however, a natural purpose is a self-organising being, i.e., such that its parts reciprocally materially produce one another (ibid., 373–374). This definition of a natural purpose is also the principle through which judgement is required to reflect, according to

Kant, on the organised beings that it encounters in nature (ibid., 376). In effect the principle tells us that: "Some products of material nature cannot be judged to be possible in terms of merely mechanical laws", but rather must be judged in teleological terms (ibid., 387).[5] This does not require us to assume, however, that organised natural beings have actually been designed (ibid., 180–182). For as we just pointed out, the concept of a natural purpose is not the same as the concept of an intentionally designed work (e.g., of art), and in any case to make such an assertion we would have to be able to cognise the ultimate purpose of nature as a whole, which (for us) is impossible (ibid., 378). This teleological principle is, rather, just a necessary subjective principle or methodological *maxim*; i.e., without the order described by the principle there would be nothing to guide us (ibid., 386), in this case through an analogy with our own purposeful activity, as we investigate self-organising natural beings (ibid., 375, 383–384).

There is a second, subjective, principle that judgement is required to employ as it reflects upon the empirical regularities that it encounters in nature. This is the principle that: "All production of material things and their forms must be judged to be possible in terms of merely mechanical laws" (ibid., 387),[6] i.e., according to laws given to judgement by the understanding as applied to matter in general, for it is only in this way that the objective cognition of material objects is possible at all (ibid., 386). Now, although both of these maxims are necessary given the nature of our cognition, according to Kant (ibid., 404, 407–408, 413), they appear to conflict, at the very least logically ("must be judged" and "cannot be judged" are clearly logically contradictory). This presents us with an antinomy—the *antinomy of teleological judgement*—which we must endeavour to resolve.

The upshot of Kant's resolution of this antinomy is as follows. First, it does not follow from the fact that something must be *reflected upon* in some manner, X, that it is fully *explainable* in those terms (ibid., 388). Thus the assertion that a given object must be judged according to X is compatible, from an ontological point of view, with the statement that it must be judged according to Y, even when X and Y, construed ontologically, disagree in some way Z, as long as Z is not something that we can determine on the basis of a possible experience. Since neither (ibid., 388, 411) the ontological construal of the mechanistic maxim, that all production of material things *is* possible in purely mechanical terms, nor (ibid., 389, 396, 406–408) the ontological construal of the teleological maxim, that some production of material things *is not* possible in these terms, are determinable by us through a possible experience,[7] the merely logical contradiction between them is harmless for the methodological purposes that they are actually required for in the scientific context (ibid., 412–413).

This said, even in the case of a material process that must be thought of in teleological terms, without any corresponding mechanism it would make no sense to call it a natural process in the first place (ibid., 413). In other words an account of a natural process may be teleological only in the sense that the mechanical part of the account, which we are anyway required to develop as far as we possibly can, must be *subordinated* to whatever purposes we posit (ibid., 413–415). It is never the case that we can omit any part of the mechanism through which a given natural purpose is continually realised and maintained.

[5]The translation is Pluhar's.

[6]The translation is Pluhar's.

[7]In the case of the teleological maxim this amounts to saying that the concept of a natural purpose is transcendent for determinative judgement (Kant, 1790, 396).

4 Kant's Successors

There is a persistent point of debate among Kant's interpreters over whether transcendental idealism is best understood as having primarily ontological or metaphilosophical import. On the former reading, the main significance of the doctrine lies in the positive assertion that things, as they exist in themselves, are not spatiotemporal and thus not constrained by Kant's synthetic a priori principles. On this reading it is clear that Kant's arguments for transcendental idealism are lacking, for as many have pointed out over the years, it does not follow (compare Kant's argument at A26/B42) from the fact that space and time are the necessary conditions attaching to our sensibility, that they cannot also be determinations of things in themselves. Indeed the latter seems to be a natural explanation of the former fact.[8]

Naturphilosophie, one of intellectual traditions that emerged after Kant, can be understood as beginning from this way of thinking and following it through. Not just a philosophical doctrine, it characterised much of the practice of early nineteenth century empirical science (Beiser 2006, 9; Richards 2013, 109; Schnädelbach 1984, 78). Building on Kant's dynamical theory of matter as well as on Kant's concept of a natural purpose, *Naturphilosophie* reinterprets the latter as constitutive for the existence of nature as such rather than as merely a regulative principle for natural inquiry (Friedman 2006, 57–58; Williams 1966, 46–47); for, it was argued, it is only under the assumption that nature, as a whole, is actually an organism that it is possible to explain the interaction between the subjective and objective aspects of our experience, both of which are just different manifestations of one and the same vital force (Schelling, 1799, 113–140). We will return to this in §6.

On the second, metaphilosophical,[9] reading of transcendental idealism, its primary significance lies in what it asserts about the kind of a priori theoretical cognition—understood in the sense of what we can say with mathematical certainty—that is possible for us, given the constraints imposed by the structure of our cognitive faculties. The so-called *neo-Kantians*, whose views were generally regarded as closer to Kant's own, although they were also concerned with metaphysical questions, can be understood as pursuing this line of thinking (Beiser, 2014, 6). Such an interpretation is metaphilosophical in the sense that it understands the central lesson of transcendental idealism to be that we must abandon the old idea that to know something objectively is to know it absolutely independently of the way it is apprehended. Rather, the standard for objective cognition is reconceptualised to be that to which all finite rational cognisers such as ourselves must agree (Allison, 2004, ch. 2).

Now, although, on this reading, transcendental idealism is primarily a metaphilosophical doctrine, there is a kind of ontological posit at its core, although this refers to the structure of our cognition rather than to the mind-independent world. In fact it was precisely in regard to the characterisation of this structure that many neo-Kantian thinkers diverged from Kant. Historically, they have been grouped into two main traditions. The earlier, so-called psychological, tradition has its roots in the ideas of Jakob Friedrich Fries.[10] Fries, like Kant, saw the goal of critical philosophy to be primarily one of explicating the a priori in cognition. Moreover he was largely (although see Pulte, 2006) in agreement with

[8] The 'neglected alternative' objection is most often associated with F. A. Trendelenburg (Beiser 2014, 212–215, Gardner 1999, 107; Kanterian 2013), but the objection was also made much earlier by others, for instance by J. G. H. Feder (Sassen, 2000, 140).

[9] This is the term used by Allison (2004, 35).

[10] See, especially, his *Neue oder Anthropologische Kritik der Vernunft* (1828).

Kant regarding the specific principles he held to be synthetic a priori. But Fries rejected the idea that there are but two faculties involved in cognition. Whereas reason, for Kant, was merely the abstract application of the faculty of understanding, or the power of deductive inference; for Fries it constituted a third, autonomous faculty, manifesting itself in a 'feeling-for-truth' (Nelson, 1971, 178–179). This yields a distinctive conception of the critical method, which for Fries is necessarily empirical: Through a philosophical analysis of the contents of specifically human cognition, we thereby 'deduce'—not in a logical but in a functional, pragmatist, sense (Beiser 2014, 76–77; Gregory 2006, 90–91; Leary 1982, 228–229; Nelson 1971, 164–196)—the a priori forms of cognition that are implicitly relied upon therein.

A second figure in the psychological tradition, whose thought would later have an important influence on Hermann von Helmholtz (who we will discuss in §5), was Johann Friedrich Herbart. Initially a disciple of Fichte, Herbart's thought gravitated towards Kant's over the course of his career. Like Kant (and Fries), he conceived of philosophy as essentially concerned with the concepts and presuppositions of experience (Beiser, 2014, 92), though he outright rejected what he took to be Kant's faulty "faculty psychology" (Beiser, 2014, 134).[11] Unlike the Kant of 1781, but like the Kant of 1770, Herbart did not restrict the applicability of the principle of causality to appearances alone, employing the key concept of a rigid body in order to bridge the gap, as Kant could not, between subjective (sensible) and objective (intelligible) space, the latter conceived in terms of what is delineated by a given collection of consistent abstract logical relations (Lenoir, 2006, 151–152, 159).

In the context of early nineteenth century philosophy, Fries and Herbart were comparatively minor figures. This was the period of the ascendancy of *Naturphilosophie*, and more generally, speculative idealism, which arguably achieved the peak of its influence through the work of G. W. F. Hegel, but fell into decline after his death in 1831. In Germany this culminated in the so-called identity crisis of philosophy (Schnädelbach, 1984, 5), and the subsequent rise of the neo-Kantians, who attempted to rehabilitate philosophy by grounding it in a theory of scientific knowledge (Beiser 2014, 6; Schnädelbach 1984, 103–108). Eventually the neo-Kantian movement was to coalesce into three main schools:[12] the Southwestern, Baden, or Heidelberg school, whose main representative in the nineteenth century was Wilhelm Windelband; the Marburg school, whose main nineteenth century representative was Hermann Cohen; and the Berlin school whose key figures during the nineteenth century were Alois Riehl and Benno Erdmann.

As a rule, the three main neo-Kantian schools repudiated psychologism in favour of an (epistemo)logical understanding of transcendental idealism; though, as Beiser explains (2014, 37, 80, 487), the difference between the psychological and epistemological traditions is not as stark as some representatives of the epistemological tradition made it out to be.[13] Cohen, for instance, was mentored at Marburg by Friedrich Albert Lange, whose views in turn had been substantively influenced by Helmholtz. But whereas Lange and Helmholtz had interpreted transcendental idealism in physiological terms, Cohen's interpretation (1871) was strictly logical. He nevertheless maintained that psycho-physiological methods were the best means to *discover* the a priori in cognition (Beiser, 2014, 487). In the

[11] Herbart's positive views on psychology can mainly be found in his *Psychologie als Wissenschaft* (1824).

[12] A fourth, neo-Friesian, school of neo-Kantianism (Beiser, 2014, 2) was to form in the early twentieth century under the leadership of Leonard Nelson (1882–1927).

[13] Part of the reason for the divergence in opinion was the shifting nature of psychology itself, which by the end of the nineteenth century had evolved into an empirical science wholly independent of philosophy (Beiser, 2014, 500).

end, Cohen's views, and those of the Marburg tradition in general, diverged in significant ways from Kant's in the sense that they denied Kant's basic distinction between understanding and sensibility. For Cohen, the distinction between the pure forms of intuition and the pure forms of thought is not truly a distinction in kind. The former are only an abstraction meant to capture the role played by sensibility in cognition (Cohen, 1871, 90–91), while the concept of the thing-in-itself is understood, not as a metaphysical concept, but as a regulative or limiting one determinable in accordance with the Anticipations of Perception (see §1), whose role in Kant's system, as Cohen explained, is to provide us with the means, as explicated formally through the methods of the calculus, with which to determine the real (Cohen 1883; for further discussion, see Richardson 2006, 219–221).

5 Neo-Kantianism and Physical Geometry

Transcendental idealism's initial impact on the development of nineteenth century science came mainly through scientists themselves rather than through professional philosophers. In the early part of the century, this was partly because the distinction between philosophy and science was a fluid one. This was especially true in the case of *Naturphilosophie* (Beiser 2006, 10; Friedman 2006, 63–68; Richards 2013; Schnädelbach 1984, 78; Williams 1966, 32–63). Even after the decline of speculative idealism, it was primarily natural scientists who initially developed the neo-Kantian response to philosophy's mid-century identity crisis (Schnädelbach, 1984, 103). At the vanguard of this movement was Helmholtz. Helmholtz had read Kant at an early age (Cahan, 2018, 44, 67), and Kant was to have a lasting impression on his thought. Echoing Kant, Helmholtz was to write, in 1855, of philosophy's essential, unavoidable, and enduring mission to enquire into the sources of our knowledge and the degree of its justification.[14]

Drawing on contemporary empirical research in physiology and psychology, and especially the physiology of sense perception as exemplified in the research of Johannes Müller (Beiser, 2014, 197), Helmholtz (1855) carefully demonstrated the extent to which our innate cognitive organisation is determinative of the nature of our representations. That in general there is such a dependence was, according to Helmholtz, exactly what Kant had aimed to show. Moreover Helmholtz argued that inference and judgement, of which we are to a large extent unaware, either through habit acquired from repeated experience, or in some cases through an innate cognitive mechanism, plays a role in shaping the very contents of our perception (Beiser, 2014, 199–200).

Echoing Kant's distinction between the series of subjective perceptions through which we apprehend an object, and the objective rule through which we connect these appearances in time (A191/B236), Helmholtz (1868; 1878) argued that sensation does not represent its object directly in the sense of an image but only indirectly in the sense of a sign. And since mathematics allows us to exactly describe the relations between signs, those relations can be understood to constitute an image of reality even if the signs themselves do not. Note that it would be a mistake to understand this way of representing reality as in some sense mind-independent, for the signs themselves represent the *interactions* between our sense organs and external things rather than the things themselves (Lenoir, 2006, 146). Space, in particular, is not some immediately given intuition of a globally Euclidean manifold, but

[14] . . . sondern sie beabsichtigte nur, die Quellen unseres Wissens und den Grad seiner Berechtigung zu untersuchen, ein Geschäft, welches immer der Philosophie verbleiben wird, und dem sich kein Zeitalter ungestraft wird entziehen können (Helmholtz, 1855, 5).

the field that we construct in order to perceive things as we interact with our surroundings, the result of complex physiological and psychological processes that are scientifically describable in a lawlike way (Beiser 2014, 204; Friedman 2013, 85).

As DiSalle (2006a, 128–129) explains, Helmholtz (1870) had shown that the first four postulates of Euclid, which circumscribe the general conditions under which constructions with straightedge and compass are possible, presuppose a more general principle: that of the free mobility of rigid bodies. Euclid's fifth, the so-called parallel postulate, by contrast, describes a global feature of space that is not determined by these general conditions on the constructibility of figures. Helmholtz was thus able to describe how the iteration of a number of basic local constructions would result in a series of sense impressions through which one could become acquainted with the global structure of a non-Euclidean space. Note how this presupposes, contra what was generally believed to be Kant's view, that whether or not a given space is Euclidean is a matter of fact, decidable through experience rather than a priori. Further, Helmholtz's analysis of how this is done highlighted the role played by the conditions for the possibility of measurement (Lenoir, 2006, 180, 201), made precise through the concept of a rigid body, as the basis for the pre-relativistic belief that the global geometry of space is Euclidean in the first place (DiSalle, 2006a, 134–136).

We note here that despite his disagreement with Kant over the a priori status of the Euclidean axioms, this very divergence may be seen as a vindication of the basic idea at the core of Kant's transcendental idealism. For, as we have seen, it had been Kant's goal to identify the general conditions under which our representations of the objects of our experience are constrained. With respect to objects as they are represented in space, Helmholtz was able to show, through his physiological analysis of the facts that lie at the basis of sense perception, that underlying Kant's own account of the basic conditions of geometrical representation lay the principle of the free mobility, specifically, of a rigid body (DiSalle, 2006a, 138), and thus he was able to show how general dynamical principles, in particular of physics, are instrumental in enabling us to determine the geometry of a given space (DiSalle, 2006b, 91). It is no wonder, then, that Helmholtz was to have such an impact on neo-Kantianism in general, both for the psycho-physiological tradition that he himself was a part of, as well as for the Marburg school which also, though in a more abstract sense, cashed out the contribution of intuition to cognition in relational terms (Beiser, 2014, 203), even if the lesson they obtained from this was primarily a logical rather than a psycho-physiological one (Schnädelbach, 1984, 104).

It is useful to, following DiSalle (2006b, 89–94), contrast Helmholtz's views with those of his contemporaries, Henri Poincaré and Bernhard Riemann. Beginning with Poincaré, who was also a Kantian of a sort: The lesson he drew from Helmholtz's analyses of the principle of free mobility was very different from the one drawn by Helmholtz. In accordance with his hierarchical view of science (Friedman, 1999, ch. 4), physical theory, for Poincaré, must be understood to be formulated against the backdrop of a particular conception of physical space and of the geometry which describes it, which, moreover, we must decide upon in advance. Although the principle of free mobility must be satisfied by any geometry capable of being given an intuitive interpretation, dynamical considerations, such as those implicit in the concept of a rigid body, cannot come into play in this decision. It follows that one must conventionally choose, among the three possible geometries consistent with the principle of free mobility, the one that is in some sense 'simplest'. Riemann, like Helmholtz, had also been substantively influenced by Herbart (Banks, 2005; Scholz, 1982). And like Helmholtz, he also took the question of physical geometry to be an empirically resolvable question that should be informed, in particular, by dynamical considerations. But

unlike both Helmholtz and Poincaré, who took the principle of free mobility to be a condition of the very possibility of physical geometry as such, Riemann was willing to accept it only provisionally until such time as a deeper understanding of the nature of dynamical interactions between bodies could be had.

6 The influence of *Naturphilosophie*

Naturphilosophie, as we discussed in §4, begins with Kant's dynamical theory of matter (§2), as well as with his concept of a natural purpose (§3), but goes beyond them insofar as it rejects Kant's distinction in kind between the sensible and intelligible aspects of our cognition. Kant's dynamical theory, of fundamental attractive and repulsive forces, is thus taken to constitutively ground nature as it is in itself, not just the matter of appearance. Importantly, the rejection of the distinction between sensibility and understanding further implies a rejection of Kant's distinction between what we can know through the understanding and through reason, since it is only the understanding's application to sensibility that distinguishes it from reason in the first place.

As Friedman (2006, 57–58) explains, the faculty of reason is both infinitary, in the sense that in its regulative use it describes a progressive process of approximation to the infinitely distant goal of the cognition of the unity and systematicity of the natural world (Kant, 1790, 185–186), as well as dialectical, in the sense that its use gives rise to antinomies that can only be resolved by recognising the transcendent nature of reason as such (A565–567/B593–595). Thus if this process is to be reinterpreted as constitutive, not just for our consideration of nature, but for its very existence, then it follows that our account of the infinitary dialectical progress of reason must have a material counterpart in an account, which is to be provided by *Naturphilosophie*, of how nature itself successively unfolds and evolves, through the fundamental attractive and repulsive forces from which inert matter is constituted in itself, into an organic form (see also Beiser, 2006, 20–21).

Naturphilosophie, through Schelling, was to have an important influence on the thought of his close personal acquaintance, the polymath Johann Wolfgang von Goethe. This influence was mutual, as his correspondence with Goethe helped Schelling to clarify certain details of his own view (Richards, 2013, 111–112). Kant had held that only mechanical accounts of natural processes could constitute explanations of them in the proper sense. It followed, for Kant, that domains of inquiry such as biology (as it existed in Kant's time), where appeals to purposes are essential and irreducible to mechanical causation, could not claim to be scientific. But Goethe argued, against this, that appealing to the idea of a purpose in the life sciences is actually no different than the appeal to a mechanical cause insofar as both are done out of necessity; i.e., appealing to purposes is, for Goethe, just as necessary in the explanation of organic processes as appealing to mechanical causes is necessary in the explanation of the possibility of experience as such. Moreover, insofar as nature as a whole must ultimately be viewed as a systematic unity and in that sense, organic, nature's mechanism must ultimately be subordinated to and for the purpose of the systematic idea of it as a whole (Richards, 2013, 109).

Goethe's work in morphology, especially his theory of the archetype, i.e., of the structure to which all of the various parts of an organism can be understood to be transformations of, was to have an important influence on the subsequent development of biology. Through the efforts of Goethe's disciples, including Carl Gustav Carus and Alexander von Humboldt, his ideas were ultimately to have a key influence on Charles Darwin (Richards,

2013, 113–117). As Richards relates, Darwin, who had become familiar with Goethe's ideas on morphology through William Whewell and M. F. G. Pictet, brought with him a number of Humboldt's works on his five year journey on the Beagle. Darwin was to give Goethe's ideas on the archetype a historical interpretation, as the form of the progenitor of a given species (Richards, 2013, 121–122). Darwin's legacy, as it is generally understood today, has been the banishment of teleology (in the ontological sense) from biology. For as Darwin's disciple Ernst Haeckel was later to emphasise, the theory of natural selection is ultimately materialistic and operates by mechanical means (Richards, 2013, 130). But in his own expositions of the theory (Richards, 2013, 129), Darwin himself continued to appeal to the concept of purpose which had played such a crucial role in its construction.

Biology was not the only field of inquiry for which *Naturphilosophie* was to have a formative influence during the nineteenth century. Kant's dynamical conception of matter, as the filling of space through fundamental forces of attraction and repulsion, suggest a kind of field theory in the emphasis that they lay upon the diffusion of force through a given space (Williams, 1966, 43). But the further step, which for Schelling had been natural in the face of contemporary developments in the study of chemical, electrical, and magnetic phenomena (Friedman, 2006, 66), of understanding all of these effects to be the result of a process whose starting point is the opposition between the two types of fundamental force (Friedman, 2006, 62), was not one which the more conservative Kant, who in the *Metaphysical Foundations* had denied scientific status to chemistry, would have been prepared to take.[15]

Schelling's ideas were to inspire the development of the kernel of a field theory by Hans Christian Oersted (Stauffer 1957, 34; Williams 1966, ch. II), which was then further developed by Michael Faraday and finally systematised into classical field theory by James Clerk Maxwell (Williams, 1966, chs. III–V). Oersted's explicitly stated methodology, as Friedman (2006, 64–66) explains, is grounded in the idea—which is the central pillar of Schelling's metaphysics—that transcendental philosophy and *Naturphilosophie*, as duals of one another, must necessarily coincide. By the middle of the century, however, Helmholtz, who blamed (somewhat unfairly) *Naturphilosophie* for the state of tension that existed between philosophy and natural science at the time, had formulated the principle of conservation of energy (Friedman, 2013, 81). This provided the means to explain all material phenomena mechanistically in terms of the principle of causality in a way that more closely accorded with Kant's own ideas, and which obviated the need to appeal to vital principles of any kind (Friedman, 2013, 81–83).

On the one hand, we can see in the examples of the nineteenth century development of biology and field theory a vindication of Kant's methodological interpretation of the principle of natural purpose. In both cases, the grand metaphysical picture provided by *Naturphilosophie*, in which the ontological interpretation of Kant's principle of natural purpose had figured so centrally, clearly guided the development of these respective theories. And yet in both cases, they eventually came to be superseded by a mechanistic account. On the other hand, one can doubt whether a merely methodological understanding of the principle of natural purpose would truly have been enough to motivate the particular empirical investigations of the scientists involved. Looking ahead from the nineteenth to the twentieth century, particularly in regards to the development of quantum theory, it was the question of how to interpret the principle of mechanism itself, either as an ontological or as a merely methodological principle, which was to come under scrutiny; and in addressing this question neo-Kantian thinkers were to play a significant role.

[15]Kant was to eventually change his mind about chemistry (Friedman, 2006, 60).

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