1 | Kant's conception of proper science

Kant is well known for his restrictive conception of proper science. In this chapter I will explain why he adopted this conception. I will identify three core conditions which Kant thinks a proper science must satisfy: systematicity, objective grounding and apodictic certainty. Kant's infamous claim that any proper natural science must be mathematical should be understood in light of these conditions. The same holds for Kant's claim that any proper natural science must be based on metaphysical principles.

The Preface to the *Metaphysische Anfangsgründe der Naturwissenschaft* (1786) contains one of Kant's few systematic attempts at specifying the notion of a proper science. Kant defines a proper science as a body of cognition that (i) is a system, (ii) constitutes a rational interconnection of grounds and consequences, and (iii) provides apodictically certain cognition. In addition, Kant states that any proper natural science must contain mathematics and be based on a metaphysics of corporeal nature.[1] The Preface does not contain a detailed explication of these conditions. Yet the implications of these conditions are rich. They enable Kant to argue that natural description (the classification of natural kinds), natural history (the historical study of changes within nature), chemistry and empirical psychology are not proper sciences.

This does not mean that Kant did not take an active interest in natural description, natural history, chemistry and empirical psychology. Recent research has shown that Kant, throughout his life, provided significant philo-

1 AA 4: 467–471.

sätze der natürlichen Theologie und der Moral (1764), Kant does recognize that mathematics contains only a few primitive concepts.[27] Moreover, in Kant's time constructive mathematical definitions were often taken to proceed from a number of primitive concepts. For example, in his *Anfangs-Gründe aller Mathematischen Wissenschaften* (1750), Christian Wolff takes constructive definitions to provide real definitions, showing how a thing is possible.[28] He argues that in geometry real definitions are easily obtained, for the motion of points given lines, the motion of lines gives planes and the motion of planes gives solids. Wolff states that if we combine points, lines, and planes in a sensible manner, and ascribe them all possible types of motion, we obtain the different geometrical definitions.[29] This procedure is worked out in detail in Wolff's discussion of the foundations of geometry, in which non-fundamental concepts are defined in terms of fundamental concepts. [30] In this manner, the method of providing constructive definitions that was common in Kant's time captures condition (2a) of the Model.

We may now turn to analytic definitions. Analytic definitions are definitions of given concepts (they are not made, as in the case of synthetic definitions). Through analysis we cognize marks of given concepts, i.e., make them distinct, and try to render them complete. In this manner, we may define concepts in terms of more fundamental concepts (contained *in* the former) by means of the traditional method of *definitio per genus proximum et differentiam specificam* (condition (2b) of the Model). The relation of genera to species is a relation of higher to lower concepts. For Kant, concepts are called higher if they have other concepts contained under themselves, which are called lower relative to the former.[31] Following de Jong, we may clarify Kant's conception on the containment relations of concepts by means of conceptual hierarchies called *porphyrian trees* (see Figure 1).

Porphyrian trees provide a paradigmatic example of a system of concepts.[32] In porphyrian trees species are specified in terms of a common genus and mu-

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27 AA 2: 279–280.
28 Wolff 1999 [1750], 12–13.
29 Wolff 1999 [1750], 16.
30 Cf. Shabel 2003, 49–57, for an account of this procedure.
31 AA 9: 146–147.
32 Anderson 2005, 47–52, stresses the representational limits of porphyrian trees. Whereas the predicables (i) 'species', (ii) 'genus', (iii) 'differentia' and (iv) 'analytic propria' can be represented in such trees, i.e., the relationship between (ii)–(iv) and (i) can be understood as a containment relationship, neither synthetic propria and accidents are contained in a species. This shows that the truth of *judgments* predicating synthetic propria or accidents of a species cannot be proven on the basis of concept hierarchies, confirming Kant's assessment of such judgments as synthetic.

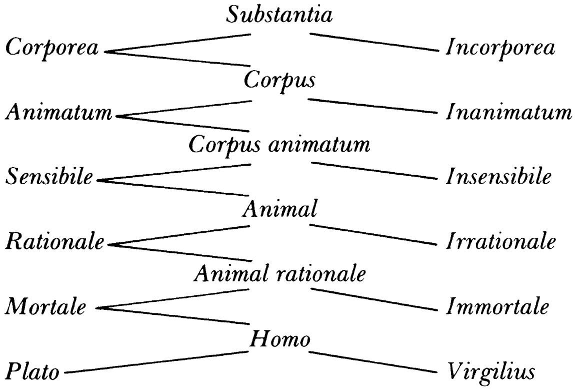

Figure 1: Porphyrian tree.[33]

tually exclusive *differentiae*. In this particular tree we specify, e.g., the species "body" in terms the genus "substance" and *differentia* "corporeal" as opposed to the mutually exclusive *differentia* "incorporeal". Both *differentia* and genus are partial concepts of the species, i.e., in Kant's terms they are *contained in* the species. Species are represented in terms of the conjunction of proximate genus and specific difference. The *differentiae* can, in turn, be represented as a species of a distinct genus and *differentia* in a different porphyrian tree. Porphyrian trees have a highest genus, in this case the concept substance.[34] In the above tree, the individual concepts 'Plato' and 'Vergilius' are taken as lowest species. However, Kant denies the existence of an *infima species*. In principle, the specification of any concept can proceed indefinitely. *Infima species* are specified by convention [35]

For our present purpose, it is important to note that according to Kant analysis provides us with the marks (e.g., "substance" and "corporeal") of a species ("body") in terms of which the latter can be defined. Analysis is a procedure through which we successively render the marks of a concept clear.[36] In this manner, analysis allows us to provide an *analytic definition*. Insofar as we can in principle successively define lower concepts (species)

[33] Taken from De Jong 1995, 624. De Jong explicates Kant's theory of concepts and analyticity in terms of porphyrian trees. Building on De Jong, Anderson 2005, 22–74, has discussed different types of analytic hierarchies of trees while emphasizing their representational limits. My account is indebted to both authors.

[34] De Jong 1995, 625.

[35] *KrV*, A 655/B 683; AA 9: 97.

[36] AA 9: 142.

A nice example of how judgments or propositions in natural science were taken to be derivable from other judgments or propositions is given by Christian Wolff.[86] We can significantly increase our understanding of Kant's conception of grounding through a discussion of this example. In §25 of chapter 4 of the *Deutsche Logik* (1754), Wolff explains that syllogistic inferences enable us to provide proofs in natural science in accordance with the mathematical (geometric) method. Wolff provides a proof of the proposition that air has an expansive force. This proposition is cognized from experience, i.e., by placing a balloon filled with air under a glass jar and by extracting the air surrounding the balloon through an air pump, resulting in the expansion of the balloon. The experiment suggest, or so Wolff claims, the following inference:

What begins to expand when resistance is removed has an expansive force. [5*]
The air begins to expand when resistance is removed. [6*]
Hence, the air has an expansive force. [7*]

Both the major and minor are proven through new inferences. The major is proven by means of an inference where the middle term provides the *definiens* of expensive force:

What continuously endeavours to expand (*in steter Bemühung ist, sich auszudehnen*) has an expansive force. [1*]
What begins to expand when resistance is removed continuously endeavours to expand. [2*]
Hence, what begins to expand when resistance is removed has an expansive force. [5*]

The major is a definition. The minor can be proved on the basis of another inference, but Wolff claims that it is sufficiently clear from experience. Hence, we can treat it as a fundamental principle (*Grundsatz*). The minor of our initial syllogism [6*] is proven as follows:

What expands a balloon when resistance is removed must also expand itself. [3*]
The air expands the balloon when resistance is removed. [4*]
Hence, the air must expand itself, when resistance is removed. [6*]

[86] Wolff 1978 [1754], 176–178. For a brief discussion of the first step of Wolff's argument, cf. Anderson 2005, 39–40.

Like proposition [2*], proposition [3*] is treated as a fundamental principle (*Grundsatz*). Proposition [4*] is taken to be true on the basis of experience. In particular: it is taken to be true on the basis of Wolff's interpretation of our initial experiment.

Through this series of syllogisms, we have specified, Wolff claims, the matter that allows us to prove the proposition 'air has an expensive force' in accordance with the mathematical method. In this penultimate proof, Wolff presents [7*] as following from [1*]–[4*].[87] [1*] can be taken to provide a nominal definition of expansive force. As such, it provides according to Wolff a true ground on the basis of which we can give proofs.[88] [2*] and [3*] are treated as certain, i.e., true fundamental propositions, while [4*] is taken to be true on the basis of experiment. The proof of [7*] from [1*]–[4*] is a proof from certain, true grounds, providing an instance of what Wolff takes to be the true method of demonstration in science, i.e., the "habit of inferring conclusions by legitimate sequence from certain and immutable principles."[89]

I do not wish to argue that Kant accepted Wolff's views on the proper, i.e., *mathematical*, method of providing demonstrations in natural science. First, we may note that Wolff's demonstration treated above provides us (at least from Kant's perspective) with an instance of what I have called (G_1) and not of (G_2). In other words, we are dealing with a demonstration that exemplifies (mere) derivability from truths. Wolff's demonstration does not, as I will argue in more detail below, exemplify a demonstration in which propositions *objectively ground* each other (G_2). Since, as I have argued, Kant adopted a conception of objective grounding in terms of (G_2), he would criticize Wolff on this count. I will return to this topic later on in this section. Second, we may note that in the Doctrine of Method of the first *Critique*, Kant famously denied that the mathematical method, based on definitions, axioms and mathematical demonstrations, can be imitated in philosophy.[90] Some of his reasons for denying that the method of mathematics is applicable in philosophy also apply to Wolff's method of demonstrating propositions of

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87 I have slightly simplified matters, since in the penultimate 'mathematical proof' Wolff additionally specifies two remarks and a corollary (*Zusatz*). The corollary provides Wolff's interpretation of the experiment, which supports [4*].

88 Wolff 1978 [1754], 145–146.

89 Wolff 1963 [1728], 17.

90 *KrV*, A 712–738/B 740–766. This argument was first developed by Kant in his *Untersuchung über die Deutlichkeit der Grundsätze der natürlichen Theologie und der Moral* of 1764.

2 | Mechanical explanation and grounding

In the first chapter we have analyzed Kant's conception of proper science. The current chapter aims to apply some of Kant's views concerning proper science to his views concerning the possibility of scientific cognition of organisms, constituting the subject matter of what we may call biology. In discussing Kant's views on the possibility of knowledge of organisms, his position as articulated in the *Kritik der Urteilskraft* (1790) constitutes the main focus of our inquiry.

A proper science satisfies the conditions of systematicity, objective grounding and apodictic certainty. Kant does not systematically discuss the possibility of cognition of organisms in light of these three conditions. In the *Kritik der Urteilskraft*, Kant does argue that organisms defy mechanical explanation. The notion of mechanical explanation has been extensively analyzed in recent literature. However, the fact that Kant construes mechanical explanation as an instance of proper scientific explanation and the reasons for why he endorsed such a view are rarely discussed. In the present chapter I aim to show why Kant took mechanical explanation to be a proper scientific explanation by relating this type of explanation to his views on objective grounding as discussed in the previous chapter. Mechanical explanations are construed as proper explanations because they specify objective grounds (the reason *why*) of phenomena.

In order to relate Kant's views on mechanical explanation to his views on objective grounding, I first discuss Christian Wolff's views relating to mechanical explanation. This will allow us to provide a more precise determination of the notion of mechanical explanation than currently presented in the literature (in which the views of Wolff are not discussed). I argue that part/whole principles (contained in *physica generalis*) of natural science.[99] Kant criticizes natural philosophers employing the mathematical method for not making this distinction, and for rejecting metaphysics while implicitly making use of metaphysical principles (in the following, we will see that this critique is also articulated in the *Opus postumum*). The target of Kant's criticism seems to be Newton, who, in the definitions and scholia of the *Principia*, introduced metaphysical principles (e.g., absolute space, inertial force, etc.) without subjecting these principles to a proper metaphysical analysis.[100] In the *Principia*, then, we have a mixing of metaphysical and mathematical principles (both pertaining to *physica generalis*). The purpose of the *Metaphysische Anfangsgründe* is, as said, to provide a distinct exposition of the metaphysical (a priori) principles grounding the mathematical cognition of nature.

4.4 Physics as presented in eighteenth-century textbooks

In the previous sections I have discussed Kant's conception of physics. In the next sections I discuss some views on physics adopted by German scientists in the latter half of eighteenth century. This discussion will allow us to determine how Kant understands physics in the *Opus postumum*.

I analyze two textbooks on physics and one dictionary, spanning the second half of the eighteenth century. These are: J.P. Eberhard's *Erste Gründe der Naturlehre* (first published in 1753), W.J.G. Karstens's *Anleitung zur gemeinnützlichen Kenntniß der Natur* (1783) and J.T.S Gehler's *Physikalisches Wörterbuch* (1787–96). I have referred to these writings in the preceding discussion of Kant. However, a more detailed discussion of these works, specifically: of the conception of physics articulated in these works, will be useful for assessing Kant's transition project in the *Opus postumum*.

Kant was familiar with all three cited works. He employed Eberhard's textbook in his lectures on physics in the 1750s and 1760s.[101] After adopting Erxleben's *Anfangsgründe der Naturlehre* from 1772 to 1783[102], Kant lectured on physics following Karsten's *Anleitung* in 1785. Both Kant's lectures, recorded as the *Danziger Physik*, and Karsten's *Anleitung* are printed in the

99 AA 4: 472–473.
100 Cf. Pollok 2001, 124.
101 For an overview of Kant's activity as a lecturer and of the textbooks employed in his lectures, see Naragon 2009.
102 I briefly mention Erxleben's *Anfangsgründe der Naturlehre* below, but will not subject this work to a separate analysis since for my purposes it does not add much to what we can learn from the other works.

Akademie-Ausgabe (to which I refer). Finally, Gehler's dictionary constituted a very influential source on physics at the end of the eighteenth century.

Historians of science sometimes refer to the late-eighteenth century and to the beginning of the nineteenth century as containing the origins of modern science.[103] It is argued that in this period the word 'science' became restricted to the investigation of nature, referring only to *natural sciences*. In addition, we witness radical developments within various experimental sciences. Here one may think of developments within chemistry associated with the so-called chemical revolution. One may also think, however, of the creation of biology and geology as autonomous sciences. In short, we witness the proliferation, differentiation and specialization of various natural sciences. In light of these developments, it is no surprise that the proper conception of physics was a point of controversy. The study of eighteenth-century textbooks on physics shows that physicists were trying to come to grips with the scientific developments within the natural sciences. In particular, they asked themselves how, in light of the differentiation of natural sciences, it is possible to still understand physics as a unified whole. It is precisely this topic that constitutes the subject of Kant's *Opus postumum*. Through the study of these textbooks we can (I contend) gain insight into several discussions concerning physics that inform Kant's transition project in the *Opus postumum*.

In the following, I describe some of the controversies concerning the nature of physics that come to the fore within the mentioned sources. These include controversies concerning: (i) the role of mathematics within physics; (ii) the status of chemistry; (iii) the importance of understanding physics as a systematic and unified science. In addition (iv), I focus on the conception of organic nature articulated by these various authors. As we shall see, although the study of organic nature is not assigned a central place within physics, it is typically treated as a part of physics (although, to be sure, the study of organisms is still placed under *natural history*).

4.4.1 Eberhard's *Erste Gründe der Naturlehre*

Eberhard's *Naturlehre* contains a standard presentation of physics in the eighteenth century. One of the main purposes of this textbook is to present physics as a systematic and unified whole. This required the delimitation of physics from other sciences, most importantly pure and applied mathematics, and a precise account of the content of physics. In specifying the content of physics,

[103] Cf. Cunningham and Williams 2003, 218–246.

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