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Kant and the Scope of Analogy in the Life Sciences

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Abstract

In the present paper I investigate the role that *analogy* plays in eighteenth-century biology and in Kant's philosophy of biology. I will argue that according to Kant, biology, as it was practiced in the eighteenth century, is fundamentally based on analogical reflection. However, precisely because biology is based on analogical reflection, biology cannot be a proper science. I provide two arguments for this interpretation. First, I argue that although analogical reflection is, according to Kant, *necessary* to comprehend the nature of organisms, it is also *necessarily insufficient* to fully comprehend the nature of organisms. The upshot of this argument is that for Kant our understanding of organisms is necessarily limited. Second, I argue that Kant did not take biology to be a proper science because biology was based on *analogical arguments*. I show that Kant stemmed from a philosophical tradition that did not assign analogical arguments an important justificatory role in natural science. Analogy, according to this conception, does not provide us with apodictically certain cognition. Hence, sciences based on analogical arguments cannot constitute proper sciences.

Keywords: Kant, analogy, eighteenth-century biology, proper science.

Introduction

In his *Vitalizing Nature in the Enlightenment* (2005), Peter Hans Reill argued that eighteenth-century biologists and philosophers interested in biology assigned analogy a privileged role in biological theorizing. Commenting on Buffon, Reill notes that "Buffon preferred analogical reasoning to discursive logic" (Reill 2005, p. 55). Commenting on Herder, Reill notes that "Herder argued that all great scientific thinkers had used analogies, which he equated with poetic imagination, to achieve their breakthroughs" (Reill 2005, p. 191). According to Herder, Reill argues, nature could only be apprehended by analogies.

The role of analogy in Kant's reflections on biology have been recently analyzed by Dalia Nassar (2016). In spite of Kant's critique on the scientific status of biological disciplines, Nassar argues that Kant laid the "theoretical foundations for the emerging science of life" (Nassar, 2016, p. 65.). Acccording to Nassar, Kant laid these foundations by explicating that biology is based on analogical reflection (Ibid, p. 58. See also Nassar 2015). Through emphasizing the role of analogical reflection in biology, Kant articulated the distinctive and special methodology of biology (Ibid, p. 65). It is important to stress that Nassar does not think that Kant believes biology is a proper science. Rather, her claim is that Kant despite himself, by articulating that biology is based on analogy, provided a new research agenda for those that came after him.

In this paper I will further develop the interpretations of Reill and Nassar. My focus will be on the theoretical roles that *analogy* fulfills in eighteenth-century biology. Although Reill and Nassar stress the importance of analogy in eighteenth-century biology, they do not highlight the specific theoretical and epistemic roles of analogy in eighteenth-century biological thought. Analogy, as I will show, was assigned the following theoretical roles: (i) analogies were interpreted as providing heuristic tools that play an indispensible role in the *discovery* of knowledge; (ii) analogies were taken to provide interpretations of abstract scientific terms thus making these terms intelligible. As such, analogy provided *scientific understanding* of scientific concepts and theories; (iii) Analogies fulfilled a *justificatory* role in justifying different scientific theories; (iv) analogies were construed as a means to construct *economical* and *unified explanations* of different phenomena.

Through analyzing the different ways in which analogies were conceptualized in eighteenth-century scientific and philosophical thought, I will further argue, in line with Nassar, that Kant took biology to be fundamentally based on analogical reflection. However, precisely because biology is based on analogical reflection, biology cannot be a proper science according to Kant. Hence, Kant took his reflections on analogy to explicate the actual theoretical foundations of biology and therefore used them to argue that biology is not a proper science. This reading does not conflict with that of Nassar, since Nassar acknowledges that biology is not a proper science for Kant. However, it does show Kant's actual intentions in reflecting on the theoretical foundations of biology. In my opinion, Kant tried to model biology on an axiomatic ideal of science that was exemplified by the mathematical physics of his day. Biology did not meet this standard of scientific rationality, a point which becomes clear if we recognize that biology is fundamentally based on analogical reflection.

I provide two arguments for this latter interpretation. First, I argue that although analogical reflection is, according to Kant, *necessary* to comprehend the nature of organisms, it is also *necessarily insufficient* to fully comprehend the nature of organisms. The implication of this argument is that Kant took our understanding of organisms to be limited. Second, I argue that Kant did not take biology to be a proper science because eighteenth-century biology was fundamentally based on analogical arguments. I show that Kant stemmed from a tradition that did not assign analogical arguments an important justificatory role in natural science. According to this tradition, analogy should be used sparingly in science and is subordinated to proper scientific explanations conceptualized as deductive (syllogistic) demonstrations from fundamental principles.

The structure of this paper is as follows. In section 1, I discuss existing research on analogy in science and Kant. Section 2 provides an overview of the manner in which analogies were conceived by philosophers and scientists prior to Kant. Section 3 provides an analysis of the role of analogy in the

biological writings of Buffon and Blumenbach. It demonstrates that eighteenth-century biology was fundamentally based on analogical reflection. In section 4, I sketch Kant's own skeptical views on analogy and relate them to the views of his predecessors. Section 5 describes the role of analogy in Kant's philosophy of biology. In the concluding section 6, I reflect on Kant's views on natural history and show that Kant was skeptical of natural history and other biological disciplines precisely because they were based on analogical reflection.

1. Analogy and Kant's Philosophy of Biology

In her *Models and Analogies in Science* (1966), Mary Hesse contrasts the views of Duhem (1861-1916) and Campbell (1880-1949) in order to identify two opposed conceptions on the use of models and analogies in science (Hesse, 1966, p. 1-6). Duhem took theories in physics to be axiomatic structures similar to Euclid's *Elements*. On this conception of scientific theory, the function of models and analogies in science is limited. They can function as psychological aids in the discovery of theories, but are not essential to the structure of science (Ibid, p. 2-3). In contrast to Duhem, the physicist Campbell argued that analogies and models are not mere aids to the establishment of theories that may be removed "once the theory is formulated" (Campbell, 1920, p. 129). Rather, since they are necessary to obtain intelligible interpretations of theories and since they enable theories to make predications in new domains of phenomena, analogies and models are an essential part of theories (Hesse, 1966, p. 4).

Hesse's contrast between the views of Duhem and Campbell provides a fruitful framework for discussing how the notion of analogy was conceived in the eighteenth century. As we shall see, eighteenth-century theorists discussed whether analogies were merely aids to the discovery of theories or if they were essential to the logic of science. Kant can be interpreted as taking a middle position between these extremes. On the one hand, Kant argued that analogies were important to scientific practice because they render abstract scientific terms intelligible. Moreover, Kant took a specific class of analogies, the analogies of experience, to be a priori principles grounding natural science. On the other hand, Kant adopted a conception of science as a hierarchically ordered whole in which scientific propositions are strictly derivable from (more) fundamental propositions. According to this conception, analogical arguments should play little to no role in scientific demonstrations.

My interpretation of the role of analogy in Kant's conception of biology builds on the work of Angela Breitenbach. Breitenbach has stressed that, according to Kant, teleological judgments do not fulfill a mere heuristic function in science but provide necessary conditions "for representing something as an organized being" (2014, p. 133). As such, teleology is a necessary condition for the possibility of biological science, since the domain or object of this science (organized nature) is identified and delineated by means of teleological concepts and judgments.[1] Breitenbach notes that, according to Kant, teleological judgments concerning the purposiveness of organisms are based on an *analogy* with human goal-directed action. It is human goal-directed action, therefore, that provides a model allowing us to represent certain objects (organisms) as purposive. It follows that by analogically reflecting on organisms as purposive, biologists are able to identify their object of research. Building on Breitenbach, Nassar concludes that analogical reflection provides the biologist with its "very object of investigation" (Nassar, 2016, p. 63).

[1] This popular view is entertained, in some form, by Quarfood (2006); Goy (2008); Toepfer (2004) and van den Berg (2014).

Moreover, analogical reflection, according to Nassar, provides the biologist with a "non-explanatory research program" in which the aim is not to explain the origins of organized beings but to illuminate the internal constitution of organisms "through principled reflection on their form and structure" (Ibid, p. 64). Nassar thinks that such a research program is exemplified by Kantian natural history.

How did Kant arrive at the idea that biological science is based on analogical reflection? By analyzing works of Buffon, Blumenbach, and others, I will show that eighteenth-century biology was a science fundamentally based on analogy. Hence, Kant's analysis of the importance of analogy in biology reflected important aspects of eighteenth-century biology practice. However, we will see that according to Kant proper sciences must provide explanatory demonstrations in which conclusions are strictly derivable from fundamental principles. Biology did not provide such explanatory demonstrations. It largely justified its conclusions through inductive analogical arguments. The fact that biological sciences heavily employed analogical arguments thus counted against their scientific status.

2. Heuristics, Justification, and Scientific Understanding

To understand how analogies were conceptualized in eighteenth-century philosophy and science, I will start by providing an overview of the manner in which analogies were treated in eighteenth-century German textbooks on logic and philosophy. Modern theorists typically distinguish between an *analogy* and an *analogical argument*. An analogy is a comparison between two (systems of) objects that highlights respects in which they are similar. An analogical argument cites accepted similarities between two systems to support the conclusion that some further similarity exists (Bartha 2013). In the following, I first discuss how analogies are treated within eighteenth-century textbooks on logic and philosophy. I will then focus on the way in which analogical arguments are presented in these textbooks.

In Reimarus' *Vernunftlehre*, an influential eighteenth-century logic textbook, an analogy is defined as a *similarity* between different objects. Objects can be analogous with respect to, among others, their properties, effects or purposes. Thus, for example, plants and animals have analogous *properties* if they have a similar structure or manner of propagation. Alternatively, the plumes of plant seeds and the wings of a butterfly have analogous *purposes* insofar as both have the purpose of propagating the species (Reimarus, 1766, pp. 291-292).

It is important to note that Reimarus does not assign analogies any role in the justification of knowledge. He does acknowledge, however, that analogies play an indispensable role in the *discovery* of knowledge. Analogies are discussed in the chapter on *discovery*. This chapter contains a discussion of the *ars inveniendi*, i.e., the art of discovering new knowledge and methods. Analogies can play an important heuristic role due to the fact that they provide insight into the *similarities* of different objects. This allows us to transfer knowledge applicable to one domain of objects, which is known, to another domain of objects, which is unknown. In his *German Metaphysics*, Christian Wolff highlighted this feature of analogies in his account of *Witz*, i.e., the capacity to observe *similarities* between different systems of objects. *Witz* is a prerequisite of discovering new forms of knowledge (Wolff, 1743, pp. 221-223). Wolff notes that in order to discover new knowledge, one must be able to *connect* that which is known to that which is unknown. This is done by observing *similarities* between different things. Wolff gives the

following example: if a child, which knows how to count money, wishes to learn arithmetical rules of addition, it may represent different species of numbers as different species of monetary coins and bills. By treating numbers and money as similar, the child may learn that the arithmetical addition rules are identical to the rules it employs when counting money (ibid). In this way, knowledge of similarity underlies the discovery of new knowledge. Since analogy is one of the most important ways to obtain knowledge of similarity, it is also one of the most important aids in the discovery of new forms of knowledge.

Reimarus and Wolff provided an account of analogies in general, defined as a similarity between objects. In his *Von dem Begriffe der Philosophie und ihren Theilen* (1778), the Wolffian Johann August Eberhard, who wrote a textbook on physics which Kant used for his lectures, provided an account of *analogical arguments*. Eberhard strictly distinguished analogical arguments from strict proofs (deductive or syllogistic demonstrations) and from knowledge obtained by means of experience (observation and experiment). They were assigned the following inductive form, familiar from modern textbooks on logic:

(i) S is similar to T in certain respects.
(ii) S has further feature Q.
(iii) Hence, T has further feature Q.

Since analogies are inductive inferences, they have little justificatory force. Eberhard accordingly argues that the importance of analogies does not lie in their justificatory force but in their *heuristic* function. In addition, analogies are construed as *provisional* arguments. They are arguments that we employ when we are not yet in the position to prove a conclusion by means of a strict demonstration or by means of observation and experiment (Eberhard, 1778, p. 21).

According to Eberhard, arguments from analogy are inferior to demonstrations or inferences based on experience. In contrast to these later types of inference, which yield propositions that are epistemically *certain*, the results of analogies are not certain but *problematic*. However, analogies do suggest further lines of investigation. Thus, for example, sometimes the results of analogical arguments are later confirmed by means of demonstrations or experience. If this happens, Eberhard argues, the analogy has served its heuristic function and becomes redundant. Eberhard notes, for example, that we have employed an analogy between moss and other plants to infer that moss reproduces through seeds. This conclusion was later confirmed by observation and thus became certain (Eberhard, 1778, p.22). It can also happen, however, that analogies provide us with conclusions that conflict with the results of experience or demonstration. In such cases, preference must be given to experience or demonstration, which, according to Eberhard, provide us with more secure ways to obtain truth. Thus, for example, the analogy between the fluids air and water may suggest to us that air, like water, is not elastic. However, experience teaches us that air is elastic (ibid, p. 21). Analogies can thus be deceptive. In science, Eberhard thinks, we must strive to provide demonstrations or inferences based on experience, and use analogies as sparingly as possible.

Eberhard's remarks on analogy are articulated within the context of an ideal of science formulated by Christian Wolff. Wolff believed that every science should follow a strict mathematical or axiomatic method (Wolff, 1963 [1728], pp. 59-78). According to this method, every non-fundamental concept of a science should be defined in terms of fundamental concepts, every non-fundamental proposition should

be syllogistically deduced from certain principles, and scientific demonstrations should proceed from true premises (grounds) that explain why something is the case (van den Berg 2013, p. 726). Within this conception of proper science, analogical arguments, a species of inductive arguments, occupy only a marginal role and are subordinated to proper scientific demonstrations. Proper justification in science is given by means of *deductive* scientific demonstrations. As we shall see, Kant also adopted this conception of science.

It is worth briefly noting that the mere heuristic status assigned to analogies did not fit scientific practice in the modern period. To see this, we may briefly consider Newton's use of analogies within his natural philosophy. In Newton's *Opticks*, analogies are frequently used to *justify* propositions in natural philosophy (see e.g. Newton, 1730, p. 109). Moreover, as McGuire has argued (1970), analogy provided a justification for Newton's third rule for the study of natural philosophy. In the next section, we will see that analogy was also assigned a justificatory function in eighteenth-century biology.

To conclude this section, we may note that in the eighteenth century analogies were also assigned a fundamental role in providing *understanding* of scientific concepts and theories. This conception of analogies was developed by Herder, who thought that analogy lies at the basis of both the invention and the comprehension of scientific theories. Herder's views on the manner in which analogy yields scientific understanding are developed in his *Vom Erkennen und Empfinden der menschlichen Seele* (1778). In this work, Herder notes that we do not know the inner properties of matter. Nevertheless, we characterize the inner properties of matter by means of central concepts of Newtonian physics, such as weight, motion, force, inertia, etc. (Irmscher, 1981, p. 85). How do we understand the meaning of such concepts? According to Herder, we know the meaning of such concepts through an analogy with ourselves. More specifically, it is through an analogy with our *bodily experience* that we can ascertain the meaning of these Newtonian concepts (Ibid). Thus, to cite some of Herder's own examples, the abstract Newtonian concept of *weight* or *heaviness* becomes understandable by analogy to a bodily yearning or longing for places where the body can obtain rest, the abstract concept of *motion* becomes understandable by analogy to a bodily drive that aims to overcome rest, and the attraction and repulsion of matter can be understood by analogy with love and hate (Herder, 1778, pp. 3-4). According to Herder, we have privileged access to ourselves, e.g., to the workings of our own body, and it is on the basis of the knowledge of ourselves and analogy that we comprehend the manner in which external nature functions. In other words, our own bodily experience functions as a model for comprehending the fundamental concepts of physics. As we shall see, Kant also understands organisms by analogy with ourselves, though he does not specifically refer to the workings of our body.

3. Analogy in Eighteenth-Century Biology

Having described the conceptualization of analogies in eighteenth-century philosophy and science, we may now investigate the role of analogy in eighteenth-century biology. I will analyze the writings of two highly influential eighteenth-century biologists: Comte de Buffon and Johann Friedrich Blumenbach. The conclusion of my analysis is that analogy was fundamental to eighteenth-century biology. I will first analyze the use of analogy in Buffon's *Histoire Naturelle*. I then reconstruct the use of analogy in Blumenbach's arguments for epigenesis and in Blumenbach's natural history.

Analogy in Buffon's Histoire Naturelle

Analogy was a fundamental methodological tool for Buffon. In the "Initial Discourse" to the *Histoire naturelle*, Buffon characterized the proper method of natural history as follows:

[…] we must try to raise ourselves to something greater and still more worthy of our efforts, namely: the combination of observations, the generalization of facts, linking them together by the power of analogies, and the effort to arrive at a high degree of knowledge" (Buffon, 1976, p. 171).

These remarks suggest that analogies help natural historians to generalize and extend knowledge. That Buffon indeed ascribes these virtues to analogies will emerge if we consider the use he makes of analogies.

Buffon frequently employs analogies as devices to argue for specific theories. This becomes clear if we consider Buffon's views on nutrition, growth, and propagation.[2] These phenomena are famously explained in terms of *organic molecules*, *internal molds*, and *penetrating forces*. Buffon adopted the view that organized beings (wholes) are composed of small organized beings (parts) that are *in every respect* similar to the whole (Buffon, 1785, p. 22). This explains, for example, why a cut off piece of polyp can produce a whole new animal. The parts of organized beings were themselves taken to be composed of *primitive organic molecules or particles* (ibid). Buffon arrived at these conclusions through analogy. He construed the following series of analogies:

$$\frac{Reproduction}{Worms} :: \frac{Reproduction}{Polypi} :: \frac{Reproduction}{Elms} :: \frac{Reproduction}{Willows}$$

(Buffon 1785, p. 17)

According to Buffon, worms, polyps, elms, and willows, as well as many other plants and insects, are organisms in which every part contains a whole that only needs to be unfolded or expanded to produce a new organism (ibid). Employing a second analogy, Buffon compared these organisms to minerals, which also consist of parts similar to one another and to the whole. Thus, for example, a grain of sea-salt is composed of an infinite number of small cubes, which themselves are composed of smaller cubes (ibid, p. 17-18). These analogies led Buffon to conclude that there are an infinite number of small organized beings which are similar to the whole organisms of which they are parts (Buffon, 1785, p. 22). It should be noted that Buffon did not take these analogies to *prove* his doctrine (ibid, p. 23). The actual proof for this doctrine was given by a series of experiments. Hence, for Buffon these analogies functioned as a way to suggest or discover a theory.

After positing the existence of organic particles, Buffon postulated the existence of internal molds. Internal molds impose an organization upon organic particles (Ibid, p. 31). Buffon took the animal body and its organs to function as internal molds, structuring particles that, for example, enter the body through food (Ibid, p. 39). The hypothesis of internal molds was again suggested by analogy. Buffon argued that just as humans employ molds to bestow a form on the external parts of matter, nature may be able to form molds that bestows on bodies "both an external and internal figure" (Ibid, p. 31). The possibility

[2] On Buffon's theory of generation, see Roger (1997) and Sloan (1992).

of this hypothesis was supported by a second analogy. According to Buffon, the existence of gravity shows that in nature there are powers that are not perceptible and that penetrate the internal parts of matter. Internal molds may by analogy be seen as penetrating the internal parts of matter and bestowing on bodies their internal form (Buffon, 1785, p. 32).[3] In this way, Buffon notes, the "supposition of internal moulds" is "founded on analogy" (Ibid, p. 32-33). Analogy thus both suggests a hypothesis and shows us that it is well founded, i.e., it shows that a hypothesis does not contain anything that is "absurd or contradictory" (Ibid, p. 31). Finally, Buffon assumed the existence of penetrating forces to explain how organic molecules are joined with internal molds (Ibid, p. 42-43).

Having assumed the existence of organic particles, internal molds, and penetrating forces, Buffon explained *nutrition* as a process in which food is consumed, organic particles of the food are separated from dead particles (which are excreted by the body), and organic particles are distributed through the body by means of penetrating forces (Ibid, p. 42). *Growth* is explained as a form of expansion that occurs through the assimilation of organic particles, obtained through nutrients and moved by penetrating forces, by an internal mold (the animal body) (Ibid, p. 39). Finally, propagation is made possible when, after organisms are fully grown, organic particles that are not used for growth are redistributed to the reproductive organs of males and females, forming a "seminal fluid" (Ibid, p. 51-52, Roger 1997, p. 129). The seminal fluids of both sexes thus contained small organized bodies which could develop epigenetically through the mixture of these fluids.

It is important to note that Buffon stressed the similarities between nutrition, growth, and propagation: they are *analogous phenomena* that can thus be explained in terms of the same causes (Buffon 1785, p. 45). Hence, it is by noticing analogies between different phenomena that we can provide economical and unified explanations of these phenomena. Buffon himself often emphasized that analogy allow us to find unified explanations. Analogy is, as Buffon puts it, a means that allows us to discover general causes of different effects (Ibid, p. 28).

To conclude, the analysis of Buffon's work shows that analogy functioned as (i) a method of discovery, (ii) as a means to suggest a hypothesis and investigate whether the hypothesis was possible (i.e., non-contradictory), and (iii) as a means to construct economical and unified explanations of different phenomena.

Analogy in Blumenbach

In his *Über den Bildungstrieb und das Zeugungsgeschäfte* (1781), Blumenbach famously developed an epigentic theory of embryological development. Blumenbach postulated a vital force, the so-called *Bildungstrieb*, as a cause of epigenetic embryological development. The *Bildungstrieb*, Blumenbach argued, directed the formation of the embryo out of not yet organized homogeneous material (van den Berg, 2014, pp. 192-193. See also Lenoir 1989; Richards 2000).[4]

[3] An anonymous referee has pointed out that Buffon's appeal to gravity seems like an appeal to authority (Newton does it too). One can also use the Newton analogy to introduce magnetic attractions or chemical affinities. I agree. However, since the appeal to gravity is essential to Buffon's argument and illustrates how Buffon uses analogy to show that a hypothesis is well founded I think it is important to mention it.

[4] In the following paragraphs and section 6, I draw on and occasionally lift sentences from my description of Blumenbach's theory of the *Bildungstrieb* and natural history given in my van den Berg 2014.

What where Blumenbach's arguments for the existence of the Bildungstrieb? His argument was fundamentally based on analogy. In his first essay on the *Bildungstrieb*, published in 1780, Blumenbach states that organic processes such as generation, nutrition, and regeneration, are similar processes (Blumenbach, 1780, p. 252). If, therefore, we can identify a force that is responsible for the regeneration of organic parts, we can reason by analogy that this force is also responsible for the generation of organisms. This was indeed Blumenbach's strategy in arguing for the existence of the *Bildungstrieb*.

Blumenbach argued that the regeneration of organic parts could not be explained by preformationist accounts. According to the preformationist theory, the regeneration of organisms is explained by assuming the existence of numerous germs in all of their parts. When organisms are injured, these germs are triggered and regenerate the injured parts. Blumenbach rejected this account, observing that when half a green polyp and half a brown polyp are put in a glass they come together (Blumenbach, 1789, p. 85-87). Hence, contrary to the preformationist account, organisms do not always regenerate by forming new organic material. Rather, organisms have a self-maintaining capacity that allows them to restore their original organization. This self-maintaining capacity was best explained by postulating the existence of the *Bildunsgtrieb* (van den Berg, 2014, p. 194). Since the Bildungstrieb was responsible for organic regeneration, analogy supported the conclusion that the *Bildunsgstrieb* was also responsible for the generation of embryo's.

Analogy also provided a fundamental role in the study of natural history. In his *Beyträge zur Naturgeschichte* (1790), Blumenbach argued that nature allows for the extinction of species and the formation of new species. The existence of fossils, whose form differed greatly from existing organisms, proved that many natural species had gone extinct. Blumenbach explained this extinction by assuming that a catastrophe had destroyed a whole "pre-adamitic creation" (Blumenbach, 1806, p. 13-18). After the catastrophe, the same forces that had brought about organisms in the pre-adamitic world, most importantly the *Bildungstrieb*, also brought forth new organisms. However, after the catastrophe the *Bildungstrieb* worked in altered circumstances on modified materials. Hence, in generating new species the *Bildungstrieb* took a direction that differed from when it generated species in the pre-adamitic world (Ibid, p. 19-20). This explained why numerous fossils exhibited a form and structure that was different from that of existing organic creatures. However, since the same *Bildungstrieb* generated organisms before and after the catastrophe, currently existing organic creatures and ancient organic creatures are of a similar type (van den Berg, 2014, p. 248).

Blumenbach's theory nicely illustrates the role that analogy plays in natural history. Blumenbach's analogical reasoning proceeds as follows: we observe that currently existing organism exhibit a specific organization and take the *Bildungstrieb* to be the cause of this organization. We then observe petrifactions of organisms that are currently extinct, but whose organization exhibits similarities (analogies!) with currently existing organisms. Hence, we infer that the *Bildungstrieb* was also responsible for the generation of organisms in ancient times. After this inference by analogy, we explain differences between the organization of currently existing organisms and that of extinct organisms in terms of a modified action of the *Bildungstrieb* (van den Berg, 2014, p. 250). It could be objected that asserting the action in the past of the same forces we study now need not be an instance of analogical reasoning. The reasoning might be that the fact that the same laws of nature that hold now also held in the past is not an analogical

inference but rather a normative presupposition of any assertion of a natural law.[5] However, I think Blumenbach's inference can justifiably be construed as an instance of analogical reasoning because his whole argument is based on the analogy or similarity between currently existing organisms and extinct petrifactions of organisms. These are not the same objects obeying the same laws, but specifically different though analogous objects obeying the same laws, and it is because these objects are analogous that we conclude they obey the same laws.

To conclude: our analysis of the works of Buffon and Blumenbach shows that eighteenth-century biological theories were fundamentally based upon analogy and analogical arguments. Analogies did not only function as devices to suggest theories, but were also assigned the function of justifying theories. In the next sections, we will see that according to Kant proper sciences should not be justified on the basis of analogy.

4. Kant's Concepts of Analogy

We have seen how, in the eighteenth century, writers employed multiple concepts of analogy. Analogy was assigned a heuristic and justificatory function, and was described as a vehicle that brings about scientific understanding. In the writings of Kant, we can discern many of these concepts. Like his German rationalist predecessors, such as Eberhard and Reimarus, Kant assigned analogies primarily a heuristic function in natural science. Like Herder, Kant assigned analogy an important role in generating scientific understanding.

Kant's most explicit comments on the concept of analogy are contained in the *Critique of Pure Reason* (Kant, 1787, A179-180/B 222). There, Kant made a strict distinction between mathematical and philosophical analogies. A mathematical analogy is simply a proportion. A mathematical analogy consists of the identity of two quantitative relations between quantities. For example, the arithmetical analogy 20/5 = 36/21, expresses the proportion that 20 is larger than 5 by an amount, namely 15, that equals the amount by means of which 36 is larger than 21. (Mellin, 1797, pp. 141 – 144).

Kant calls mathematical analogies *constitutive*. They are constitutive because if we know three members of a mathematical analogy, we can a priori construct the fourth member (Kant 1787 A179/B222). Philosophical analogies are contrasted to mathematical analogies. Philosophical analogies express the identity of two relations between *qualities* as opposed to quantities. Like mathematical analogies, they have the form "A stands to B as C stands to D", where A, B, C and D express qualities. Here, one may think of analogies such as "seed is to tree as egg is to bird".

The most important difference between philosophical analogies and mathematical analogies is that philosophical analogies are *regulative* as opposed to *constitutive* (Kant, 1787, A179-180/B222). This is to say that if we know three members of a philosophical analogy, we cannot, as is the case for mathematical analogies, a priori construct the fourth member. Through philosophical analogies, all we know is the *relation* existing between the (known) third member and the (unknown) fourth member. For example, if we see a house, we know that this house is the product of human reason. If we subsequently

[5] Thanks to an anonymous referee for pressing this point.

see the constructions of a beaver, i.e., their dams, canals and lodges, we can ask ourselves the question: which cause produced these constructions? This example provides us with three elements of the philosophical analogy "house stands to human reason as the constructions of a beaver stands to …." (Mellin, 1797, pp. 149-150). According to Kant, we do not have the means to a priori construct the fourth member of this analogy. This analogy only tells us that the relation existing between the first two members, i.e., the relation between effect and cause, is identical to the relation existing between the third and the fourth member. In other words, the analogy tells us that the fourth member must contain the cause of the constructions of the beaver, just as reason is a cause of the building of the house. Through this analogy, we are thus given a rule to search in experience for the fourth (unknown) member of the philosophical analogy. This rule can be articulated as follows: search for that which allows a beaver to build dams, canals and lodges just as human reason allows humans to build houses. We are, in other words, invited to search for an analogue of human reason. The upshot of this analysis is that by calling philosophical analogies regulative, Kant stresses, just as his many contemporaries, the heuristic function of analogies. Philosophical analogies provide us with rules on the basis of which we can investigate nature in order to obtain new knowledge. It is ultimately only through experience, however, and not by means of the mere analogy itself, that we can obtain such knowledge. As Kant puts the point himself: through analogy we may be able to infer to some existence, but we "still would not be able to cognize it determinately" (Kant, 1787, A 178/B221).

In the *Critique of Judgment*, Kant notes that *instinct* is the cause of the artful constructions of animals, such as the dams of the beaver (Kant 1902, V, p. 464). Thus, the analogy we have been considering is as follows: "house stands to human reason as the constructions of beavers stands to instinct". It is probable that Kant's statement is influenced by Reimarus. In his *Allgemeine Betrachtungen über die Triebe der Thiere*, Reimarus argued that the artful constructions of animals are the result of instincts or *Kunsttriebe*. Reimarus' accordingly construes instincts as *analogues of reason* (Reimarus, 1762, pp. 21-24). However, instinct and reason are specifically different. One argument for this claim is that human activities guided by reason must be learned and require experience. By contrast, the instinctive actions of animals were taken to be innate and hereditary: instinctive actions of animals, such as the spider weaving it's web, are fully formed at birth (Reimarus, 1762, p. 250. Richards, 1987, p. 30). Kant would, I suggest, interpret Reimarus' investigation as being guided by analogy: he is searching for capacities in animals that are analogous to human reason. However, Reimarus acknowledged that analogy alone cannot establish that animals have reason and provided empirical proof for the claim that instincts are specifically distinct from reason. As such, analogy provided a heuristic guide for Reimarus but nothing more: it is empirical evidence that suggests the cause of the artful constructions of animals.

Next to assigning analogies a heuristic use, Kant also devoted comments to the structure of analogical arguments. In his *Lectures on Logic*, Kant, like his contemporary Eberhard, assigns analogical arguments the following inductive form:

(i) S is similar to T in certain respects.
(ii) S has further feature Q.
(iii) Hence, T has further feature Q.

(Kant 1902, IX, pp. 132-133)

Since analogies are a species of inductive inference, Kant thinks they can only provide us with probable, as opposed to apodictic cognition. In science analogies may sometimes be unavoidable, but we should nevertheless always strive to provide strict syllogistic proofs from apodictic principles in science. The lowly status assigned by Kant to analogical arguments (and induction) is nicely illustrated by the following quote:

> Analogy and induction are merely crutches for our understanding. For in universal propositions of truth we will always be able to proceed according to logical strictness, but in the use of our cognition (*a posteriori*) we often have to make do with the probable too. (Kant 1902, XXIV, p. 287)

Analogies are, according to Kant, subordinated to proper scientific demonstrations or explanations. What does a proper scientific demonstration or explanation look like according to Kant? In the *Jäsche Logik*, Kant argues that in a science (true) judgments must be logically grounded, which implies that they have grounds from which they are derivable (Kant 1902, IX, pp. 51-52. Falkenburg, 2000, pp. 368-370). In addition, Kant takes the judgments figuring in scientific demonstrations to be true (Kant 1902, IX p. 121). Kant further claims that proper sciences must be based on a priori principles and that proper scientific demonstrations proceed from (one or more) a priori principles (Kant 1902, IV, pp. 468-469). This fact secures that the conclusions of scientific demonstrations are apodictically certain. Scientific proofs based on mathematical (a priori) premises, as provided by Newton in his *Principia*, provide a clear example of demonstrations proceeding from a priori principles. Finally, in his *Nova dilucidatio*, Kant argues that in order to objectively explain a judgment β in natural science we must specify the *objective* ground or *cause* of what is asserted by β (Kant 1902, I, pp. 391-394). This means that we must reason from cause to effect. To summarize the foregoing: a set of judgments α objectively demonstrates or explains a judgment β, if (i) β is derivable from α and (ii) α and β are (contain) true statements, (iii) α contains one ore more a priori judgments, and (iv) α specifies the cause for what is asserted by β. This conception of scientific demonstration resembles what the medievals called a *demonstratio propter quid*, i.e., a demonstrations that explains *why* something is the case (van den Berg 2011). Analogical arguments clearly fall short of this ideal of scientific demonstration. They are inductive arguments that do not yield apodictic certainty and do not explain why something is the case.[6]

Given Kant's ideal of scientific demonstration, it is not surprising that he often denies analogies any justificatory function in science. However, it is important to note that Kant does assign such a function to the analogies of experience, which constitute the heart of the first *Critique*. According to Kant, analogies of experience, such as the principle of causality, constitute rules which further the unity of experience (Kant, 1787, A 180/B222).[7]

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[6] An anonymous referee has stated that Michael Friedman, in his *Kant's Construction of Nature* (2013), has provided evidence that Kant was not as wedded to certainty as I claim. More specifically, the referee reads Friedman as claiming that (a) mathematical construction was not the only form of construction that Kant was interested in in the *Metaphysical Foundations*; (b) it is dynamical-metaphysical constructions that Kant preferences; (c) these dynamical constructions can only yield contingent knowledge. A detailed account of my views on Friedman will have to be given in a separate paper. Here, I can say that my account is in line with Kant's construal of science given in the Preface to the *Metaphysical Foundations*, in which Kant claims that scientific knowledge must be apodictically certain and thus based on a priori (mathematical and metaphysical) principles.

[7] This is also stressed by Callanan 2008.

In order to understand the function of Kant's analogies of experience, we may turn to Newton's comments to the third rule of natural philosophy. There, Newton claims that if experiments and observations establish that all bodies near the earth gravitate toward the earth, that the moon gravitates toward the earth, that the sea gravitates toward the moon, and so forth, the third rule allows one to concluded that *all* bodies gravitate toward one another (Newton, 1999, pp. 795-796). Kant would interpret this argument as follows: the analogies of experience, in particular the principle of causality, direct us to construct a series of analogies in order to unify experience. Thus, for example, the principle of causality directs us to construct analogies that say that just as the orbit of the moon is caused by gravity, so too the motion of the sea is caused by some unknown cause (which turns out to be gravity). Hence, the principle of causality prescribes us to construct analogies of the form a:b :: c:d. Note that the fact that gravity is the cause of all these motions is not justified by the analogy itself. Rather, the analogy guides our research and directs us to discover that gravity is the cause of all these motions. This is also illustrated by the fact that Newton proves that gravity is the cause of all these motions not on the basis of analogy, but on the basis of mathematical principles, astronomical observations, the laws of motion, and so forth. Hence, the principle (or analogy) of causality is, employing Kant's terms, *regulative*: it directs us to search for the (same) causes of (similar) effects, thus unifying our knowledge. Here we see that Kant, like Buffon, acknowledged that analogies are means to obtain unified and economic explanations of natural phenomena.

The analogies of experience have a justificatory function insofar as they are conditions for the possibility of experience and ground Kant's laws of mechanics, which are described in the *Metaphysical Foundations of Natural Science*. It is important to note, however, that *analogical arguments* do not play a role in justifying the analogies of experience or the laws of mechanics. The analogies themselves are justified by transcendental arguments, while the laws of mechanics are justified either by transcendental arguments or are deduced from the analogies of experience.[8] Hence, although the analogies of experience play an important justificatory role in science, analogical arguments do not. In denying analogical arguments a substantive role in science, Kant follows many of his contemporaries.

To conclude this section, we may note that Kant argued, like his contemporary Herder, that analogies serve as a means to *understand* philosophical and scientific concepts. We understand a concept if we can apply this concept to concrete instances or inuitions of this concept (Kant 1902, IX, p. 62). There are concepts, however, that we cannot directly elucidate by means of intuitions. Whereas we have intuitions of dogs and can comprehend the concept of dog in terms of these intuitions, we do not have intuitions of the concept of a despotic state, to cite Kant's own example (Kant 1902, V, p. 352). We do not intuit a despotic state as such, and hence cannot comprehend the concept of a despotic state by means of intuition. The same is true for many other philosophical and scientific concepts, such as 'ground' or 'substance' (ibid). How are we to comprehend such concepts?

According to Kant, we comprehend the meaning of concepts that we cannot directly intuit through analogy. Through analogies, we *indirectly* associate an intuition with a concept and thus elucidate this concept. Thus, for example, Kant notes that the concept of a despotic state can be made comprehensible by means of an intuition of a handmill. The intuition of a handmill is not, of course, an intuition of a despotic state. However, the handmill is *analogous* to a despotic state, insofar as it is a

[8] See Watkins 1998.

machine that is governed by a single absolute will, just as a despotic state functions like a machine governed by a single absolute will. A handmill thus provides us with an analogical or *symbolic* representation of the concept of a despotic state and, as such, allows us to understand this concept symbolically (ibid).[9]

5. Analogies in Kant's Philosophy of Biology: Organisms and Human Purposive Action

What role does analogy play within Kant's philosophy of biology? According to Kant, our subjective understanding of the nature of organisms is based on analogy. Kant argues that we conceptualize organisms in accordance with a "remote analogy with our own causality in accordance with ends" (Kant 1902, V, p. 375). How should we understand this analogy? In the following, I will argue, adopting a traditional interpretation, that Kant wishes to draw an analogy between the human construction of artifacts and the nature and functioning of organisms.[10]

In order to understand how Kant constructs the analogy between artifacts and organisms, we must first describe how Kant conceptualizes the nature of organisms. In §64 of the *Critique of Teleological Judgment*, Kant describes organisms as objects that are cause and effect of themselves. To elucidate this phrase, Kant provides descriptions of observable characteristics of organisms, including propagation, nutrition and growth and self-preservation. Kant's descriptions of these characteristics are meant to elucidate that in organisms the parts are reciprocally dependent upon the whole (van den Berg, 2014, pp. 128-139) Organic phenomena are phenomena in which the parts cause the whole, and conversely the whole causes the parts. Schematically: A (parts) → B (whole) → A (parts). For example, while describing propagation, Kant, who adopts Buffon's idea that species are sequences of reproducing organisms (Kant 1902, II p. 429), argues that individual organisms (parts) constitute the species (whole), which, understood as a lineage of reproducing organisms, in turn makes the generation of individual organisms (parts) possible (Kant 1902, V, p. 371).

Kant argues that the causal sequences characteristic of organic phenomena cannot be understood on the model of efficient causality, since the latter model is unidirectional. According to the model of efficient causality, the parts can cause the whole, but we cannot say, conversely, that the whole causes the parts (Kant 1902, V, p. 372). We must therefore refer to a model of final causality. This model, Kant claims, allows us to understand the reciprocal causality that characterizes organic phenomena. According to the model of final causality , "the thing which is on the one hand designated as an effect nevertheless deserves, in ascent, the name of a cause of the same thing of which it is the effect" (Ibid). Kant illustrates this causal nexus by means of the example of a house that is the cause of the sums that are taken in as rent, while conversely the representation of this income was the cause of the construction of the house. How are we to understand this model of final causality?

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[9] The relation between analogy and symbolic understanding has been stressed by Breitenbach 2009, pp. 70-75. See also Nassar 2015, p. 248-252.

[10] Breitenbach (2009) has rejected this reading of the analogy, arguing that Kant draws an analogy between organisms and reason. However, even Breitenbach acknowledges that Kant does assign special importance to the analogy between organisms and artifacts. In the following, I will argue that there are good historical and textual reasons for taking Kant to draw an analogy between organisms and artifacts, since Kant adopts a Wolffian model of final causality that is based on an analysis of the production of artifacts.

Kant most likely took his ideas concerning the nature of the *nexus finalis* from the Wolffian tradition. In his *Philosophia prima sive ontologia*, Wolff provided an analysis of final causation that matches the analysis given by Kant.[11] Wolff construes a cause as follows: if the existence of a being *b* depends on being *a*, *a* is the cause of *b* (Wolff, 2001, p. 652-653). If an architect, through some acts, is the cause of the existence of a building, the architect is the *efficient* cause of the building. A final cause is that for the sake of which an efficient cause acts (Wolff, 2001, p. 678-679). If the architect constructed the house because she desires money, money is the final cause. The objective to obtain money causes the architect to build a house, and the house, in turn, is the cause of obtaining money. More specifically, the *idea* to obtain money (the final cause), leads the architect to conceive of a plan or representation of the whole (formal cause). In accordance with this representation of the whole, the architect constructs the house, which in turn leads her to obtain money. This analysis of final causation closely matches Kant's analysis of final causation and suggests that Kant's analysis was modeled on a description of the human construction of artifacts.

How does this model of final causation allow us to understand organic phenomena? Note that in the example of the building of a house, we do *not* have to do with true instances of reciprocal causal sequences. For it is the *representation* of money that leads the architect to build a house, which, in turn, generates money. Schematically: A (*representation* of money) → B (formation of a *representation* of the whole) → C (construction of the house) → D (obtaining money through rent). Hence, we are dealing with a unidirectional causal sequence. Kant's objective thus seems to be, as Paul Guyer has aptly noted, to "reconcile the reciprocal causation that we observe in organisms with the only form of causation we actually understand, progressive or unidirectional causation, by thinking of organisms as if their complex organization is the product of an antecedent design for them which is part of an intelligible unidirectional causal sequence" (Guyer, 2001, p. 265). What defies explanation according to our ordinary model of causation in the case of organic phenomena is the apparent influence of the whole on the parts. This kind of backwards or downwards causation is only explicable by analogy with the intentional production of an artifact, in which a *representation* of the whole determines the position and function of the parts. In the case of an artifact, however, we are not dealing with proper downward or backward causation. The point of Kant's analogy is to explain away this downward or backward causation, by treating organisms as if they are designed in accordance with a representation of the whole.

How, then, should the analogy between artifacts and organisms be spelled out? We can claim that artifacts and organisms are deemed to be analogous because in both objects the parts seem to be dependent upon *the idea of the whole*. If we adopt this way of thinking, we can say that, for both artifacts and organisms, the idea of the whole is the real (efficient) cause of the parts, the parts of organisms are the real (efficient) cause of the whole, whereas the whole itself, or some further function, is the ideal (final) cause of the parts. Kant thus vehemently denies an actual influence of the whole itself upon the parts.

The upshot of my analysis is that the analogy between the human production of an artifact and organisms is limited. Kant himself emphasized this point by pointing to the limits of the analogy between artifacts and organisms. Thus, for example, artifacts, in contrast to organisms, do not regenerate lost or injured parts, nor do they reproduce themselves as organisms do. Since the analogy between artifacts and

[11] A similar analysis of final causation can be found in Baumgarten. See van den Berg 2014, p. 92-98.

organisms is limited, it follows that the idea of organisms as an object of design is, according to Kant, only a regulative principle used for heuristic purposes (Kant 1902, V, p. 375). Kant himself thus stressed and welcomed the limitations of the analogy between artifacts and organisms in order to argue that the idea of an organisms as an object of design is merely regulative.

In short: Kant used a remote analogy to provide us with subjective understanding of organic phenomena. The reciprocal dependency between parts and whole, encountered in organisms, is partly comprehended by referencing the human production of artifacts, in which a representation of the whole determines the parts. However, the analogy is limited. It does not provide us with a *model* of the downwards causation that organisms manifest. Rather, downward causation is explained away. The skeptical upshot of Kant's analogy is that fundamental features of organisms cannot be fully comprehended.

To conclude this section, we may briefly consider a second analogy that Kant considers, namely the analogy between organisms and life. In §65 of the Critique of the Teleological Power of Judgment, Kant, referring to the self-organization of organisms, says that "one comes closer to this inscrutable property if one calls it an analogue of life" (Kant 1902, V, p. 374). In the *Critique of Practical Reason*, Kant defines life as "the power of being to act in accordance with the laws of the faculty of desire". The faculty of desire is "the faculty for being through one's representations the cause of the reality of the objects of these representations" (Kant 1902, V, p. 9. Cf. Ingensiep 2009). Hence, only beings that have desire or that act in accordance with representations are alive. The point of this analogy is thus to stress that organisms, like humans, are conceived as beings that are capable of purposive action. Humans act purposefully in accordance with representations. I can act on my representation of a drink (and my desire to drink) and obtain the drink. Similarly, I can act purposefully on my representation of losing weight and go to the gym. We can, by analogy, attribute this capacity of purposeful action (acting in accordance with representations) to animals and plants to explain their apparent purposeful behavior. Kant notes, however, that this analogy is also limited, since it may involve attributing life to matter (hylozoism, which Kant rejected) or it may involve assuming a soul standing in communion with matter, which does not make organisms comprehensible. Hence, Kant concludes that strictly speaking "the organization of nature is therefore not analogous with any causality that we know" (Kant 1902, V, p. 375). Analogies, therefore, can provide us only with limited understanding of organisms.

6. Analogy and Kant on Natural History: Concluding Remarks

In §4, I have shown that Kant belonged to a philosophical tradition that was critical of the role of analogical arguments in science. According to this view, analogy is subordinated to deductive scientific demonstrations, which yield proper scientific explanations and justification. In §3, we have seen that many eighteenth-century biological theories did not contain deductive scientific demonstrations. Through analyzing the works of Buffon and Blumenbach, we concluded that influential late eighteenth-century biological theories were based on analogical arguments. Such analogical arguments only provide us with weak inductive support for scientific theories, and do not, according to Kant, allow us to establish biology as a proper science. In this final section, we will see that Kant indeed devalued the epistemic status of specific biological disciplines because they did not contain proper scientific explanations and were based on analogy. This will become clear if we focus on Kant's views on natural history.

In many of his writings, Kant made a strict distinction between natural description and natural history.[12] Natural description is a mere classificatory and descriptive discipline that divides natural things in accordance with their similarities. By contrast, natural history aspires to be a historical and explanatory discipline. In his *Über den Gebrauch teleologischer Principien in der Philosophie* (1788), Kant describes natural history as a discipline that provides knowledge of relations between present properties of natural objects and their historical *causes* (Kant 1902, VIII, pp. 161-162). We have seen an example of this type of natural history in §3, when we discussed Blumenbach's *Naturgeschichte*.

Kant's views on scientific explanation, which prescribe us to provide causal explanations of phenomena, suggest that he gave theoretical preference to natural history (a possible explanatory discipline) over natural description (a mere descriptive discipline). In his early writings, Kant makes this point when he writes that natural description merely brings creatures under names, whereas natural history brings them under laws (Kant 1902, II, p. 429). In my view, Kant retains this theoretical preference throughout his philosophical career, since he never gives up the ideal that sciences should be explanatory. Hence, I cannot follow Nassar when she claims that Kant took natural history to be an example of a *non-explanatory* research program in biology (Nassar, 2016, pp. 64-65). As late as the third *Critique*, Kant describes the attempt of the archeologist of nature to derive the generation of many animal genera from a common schema or origin as an application of the principle of *mechanism*, a principle which aims to *explain* nature (Kant 1902, V, p. 418).

However, as Philip Sloan (2006) has persuasively argued, Kant did strictly limit the epistemic pretensions of natural history in the 1780s and 1790s. Kant denied that natural history can be a science of origins. He also denied that we can use natural history to argue for evolution or to provide a full-blown mechanical account of the origin of organisms. Moreover, In the third *Critique*, Kant notes that natural history provides "no hope for certainty" although there is "reasonable ground for making conjectures" (Kant 1902, V, p. 428). The epistemic shortcomings of natural history can be understood if we consider that natural history is based on analogy. In natural history, we use analogy to argue that forces presently active have also been active in the past and have produced similar effects. Thus, Blumenbach used analogy to argue that the *Bildunsgtrieb*, which is responsible for the form of currently existing organisms, is the cause of previously existing but now extinct organisms (whose form is similar to the form of existing organisms). In the first *Critique*, as we have seen, Kant notes that through such analogical inferences we cannot with *certainty* infer to the existence of certain forces or objects, since existence claims must be

[12] As Philip Sloan (2006) has shown, Kant first introduces the distinction between natural history and natural description in 1775, in a prospectus announcing his summer anthropology lectures. There, he treats natural history as a historical discipline that considers the changes that organisms have undergone through natural migrations. Natural history classifies animals and plants according to relations of generation, i.e., it adopts Buffon's rule that species are constitued by fertile propagation. By contrast, natural description is construed as a mere descriptive discipline that provides a scholastic classification of animals and plants based on similarity (Kant 1902, II, pp. 429-430, 434n). In 1788, in the wake of his controversy with Herder and replying to Forster's criticism of the distinction between natural history and natural description, Kant limits the explanatory scope of natural history, arguing that natural history cannot be a science of the (ultimate) origins of organisms (Kant 1902, VIII, p. 161). In the third *Critique* (1790), Kant further developed this point, criticizing speculative theories of the origin and development of organisms such as proposed by Herder and Buffon (Sloan 2006). Although Sloan is correct in arguing that Kant limited the explanatory scope of natural history, I maintain that Kant always gave theoretical preference to natural history over natural description because natural history was, in contrast to natural description, an explanatory discipline.

based on observation. Through analogy, as Kant puts it, we may be able to infer to some existence, but we "still would not be able to cognize it determinately" (Kant, 1787, A178/B221). Hence, although we may tentatively conclude to the existence of a *Bildungstrieb* in ancient times, we cannot cognize it determinately, i.e., we cannot, for example, conclude that the *Bildungstrieb* had the same intensity as *Bildunsgtrieb* now operative in nature. In fact, even the inference to the existence of the *Bildungstrieb* remains problematic, since existence claims must be based on observation and empirical evidence, and such evidence is sparse in a discipline which deals with forces active in historical and long past times. In short: the fact that natural history is a historical discipline that is based on analogy and where empirical evidence is sparse, explains why in natural history there is no hope for *certainty*.

Although natural history provides no hope for certainty, certainty can be found in mathematical physics. Newtonian physics was, for Kant, based on a priori principles of mathematics and metaphysics. These a priori principles can be applied to phenomena and used in explanatory demonstrations yielding apodictically certain conclusions. Our analysis of analogy in biology thus highlights that Kant, although he noted important differences between biology and physics, interpreted biology from the perspective of a philosopher who adopted a roughly axiomatic ideal of science. In the *Metaphysical Foundations*, Kant wrote that any doctrine of nature should become part of a unified science of nature and aspire to become a proper science: "every doctrine of nature must finally lead to natural science and conclude there" (Kant 1902, IV, p.469). Kant's reflections on the method of biology were a constant reminder that biology did not yet fulfill this ideal of science.

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