Submission to *Studies in History and Philosophy of Science*:

Kant's universal conception of natural history

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Abstract: Scholars often draw attention to the remarkably individual and progressive character of Kant's *Universal Natural History and Theory of the Heavens* (1755). What is less often noted, however, is that Kant's project builds on several transformations that occurred in natural science during the seventeenth and eighteenth centuries. Without contextualising Kant's argument within these transformations, the full sense of Kant's achievement remains unseen. This paper situates Kant's essay within the analogical form of Newtonianism developed by a diverse range of naturalists including Georges Buffon, Albrecht von Haller and Thomas Wright. It argues that Kant's universal conception of natural history can be viewed within the free-thinking and anti-clerical movement associated with Buffon. This does not mean, however, that it breaks from the methodological rules of Newtonianism. The claim of this paper is that Kant's essay contributes to the transformation of natural history from a logical system of classification to an explanation for the physical diversity of natural products according to laws.

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> [Buffon] felt obliged above all to mark out the route which leads to science. This route, according to him, consists *in working at the description and at the history of the various things which science has as its objects*.
>
> Guillaume-François Berthier, *Journal de Trévoux*, 1749

1. Introduction

Scholars often draw attention to the remarkably individual and progressive character of Kant's *Universal Natural History and Theory of the Heavens* (1755). In 1818 Samuel Taylor Coleridge (1969, 808) described Kant's early book as an 'astonishing *prophetic work.*' While most natural historians in the eighteenth century saw the description of natural products as a separate task from natural philosophy, which is concerned with the universal laws of nature, Kant collapses both tasks together. The subject matter of his natural history, Coleridge exclaims, is nothing less than nature itself. Martin Schönfeld (2006a, 2006b) has more recently argued that several of Kant's theoretical innovations, including the connection between force and space and the nebular hypothesis of cosmological formation, have been confirmed by modern physics. Kant brilliantly combines debates over the ontological status of force with a descriptive cosmology to develop a law-governed account of planetary movements that anticipated several key discoveries in the twentieth century.

What is less often noted, however, is that Kant's project builds on several transformations that occurred in natural science during the seventeenth and early eighteenth centuries. At the close of the seventeenth century a number of fundamental epistemological assumptions had been established, including the guiding use of mathematics in the study of nature and the fundamental role of natural history in providing the inductive foundation for natural philosophy. Within this framework natural history did not have a significant theoretical function of its own. Rather, through careful description of the works of nature it served as a storehouse of facts for theoretical examination by natural philosophers. In the Preface to his *New Experiments Touching the Spring of the Air* (1660) Robert Boyle explains that the point of natural history is not

> to establish Theories and Principles, but to devise Experiments, and to enrich the History of Nature with Observations faithfully made and deliver'd; that by these, and the like Contributions made by others, men may in time be furnish'd with a sufficient stock of Experiments to ground *Hypotheses* and *Theorys* on. (Boyle 1744, III 12)

At the opening of the eighteenth century, John Harris defined natural history in his influential *Lexicon Technicum* in the following way:

> *Natural History* is a Description of any of the Natural Products of the Earth, Water or Air, such as Beasts, Birds, Fishes, Metals, Minerals, Fossils, together with such *Phaenomena* as at any time appear in the material world; such as Meteors &c. (cited in Sloan & Lyon 1981, 2)

The prevailing view of natural history during the early eighteenth century still envisaged a descriptive project that provides natural philosophy with a storehouse of facts. In this context, Kant's *Universal Natural History*, which offers a general account of the present diversity of nature as the result of a developmental process, embodies a radically different conception of what natural history is meant to achieve. Kant's expressed intention is to present a hypothesis of the origin of the universe, a cosmogony that accounts for its development from a chaotic nebula to the highly structured system we see today exclusively through attractive and repulsive forces.

It is a matter of convention in Kant scholarship to view *Universal Natural History* as a manifesto for Kant's 'conversion to Newton' (Schönfeld 2000, ch. 4). The subtitle Kant originally ascribed to the book ('An essay on the constitution and mechanical origin of the whole universe treated according to Newton's principles') renders his intentions clear. Yet to frame one's conversion to Newtonianism within a natural history, one that draws physics together with a hypothetical cosmogony, seems at odds with Newton's mathematical project in *Principia*. Inspired by Kant's later defence of universal gravitation in *Metaphysical Foundations*, scholars give attention to his attempt to apply Newton's mathematical method to the domain of physics. Schönfeld (2000, 97) identifies *Universal Natural History* as part of the initial phase of Kant's 'precritical project', namely, the endeavour to build 'a comprehensive philosophy of nature, with its complex tasks of constructing new justifications of metaphysical *desiderata* and of revising Newton when necessary.' Michael Friedman (1992, 18-19, 10) claims that 'Kant takes Newtonian attraction as a given datum', and thus attempts to silence those who maintain 'metaphysical doubts about Newtonian attraction' by showing its compatibility with 'Leibnizian-Wolffian' metaphysics. The text begins Kant's attempt to undertake a 'fundamental philosophical reconsideration of Newtonian physics', which finds full expression in *Metaphysical Foundations* (Friedman 1992, 11).

Yet philosophical reconsiderations of Newtonian physics were not uncommon in the mid-eighteenth century, and Newtonianism had become a dynamic programme well before Kant's essay. While Schönfeld and Friedman trace a direct link between Kant and the mathematical procedure of Newton's *Principia*, Michela Massimi (2011) has recently argued that the dynamical parts of Kant's cosmology, which Schönfeld and Friedman attribute to Kant's Leibnizian-Wolffian metaphysics, can be attributed to a materialist tradition of Newtonianism that emerged in the early eighteenth century. This tradition drew from a much wider range of Newton's works, including Newton's pre-*Principia* letters and, most importantly, the *Opticks*, where Newton offers a more speculative presentation of basic forces. Drawing on Robert Schofield's topology of Newtonianisms, Massimi (2011, 531, 533) interprets Kant's dynamical account of matter as an 'idiosyncratic blend' of Newton, Stephen Hales and Herman Boerhaave, the 'hybrid result of both the mechanical *and* the materialistic tradition, to use Schofield's terminology, both originating from Newton's theory of matter.' Massimi highlights Kant's mechanical explanation of the formation of particle vortices, which differs from the more speculative account provided by Descartes and the Greek atomists. Yet in contrast to Newton, Kant saw attraction as an 'essential force' inherent in matter. Massimi (2011, 529) concludes that in Kant's hands 'Newtonian attraction became *immanent [in] fine matter* and via a mechanical mode, it became one of the causal agents responsible for the constitution of the universe.'

Massimi provides a more complex account of Kant's so-called 'conversion to Newton' than Schönfeld and Friedman, highlighting the importance of the various Newtonian projects of the early eighteenth century in shaping Kant's method in *Universal Natural History*. Yet Massimi, like Schönfeld and Friedman, fails to identify the sense in which Kant's essay is a work of *natural history*, that is, why a theory of matter should feature within a historical account of nature rather than a straightforward work of philosophy or speculative physics. This obscures the full significance of Kant's achievement, which, I will argue, is to transform what it means to provide a natural history from constructing a logical system of classification to providing an explanation for the present diversity of things according to laws.

To make this argument I build on Charles Wolfe's (2014, 223) topology of eighteenth century Newtonianisms, which, developing Schofield's account, identifies three distinct research programmes: experimental, methodological and analogical Newtonianism. I suggest that Kant's *Universal Natural History* extends the analogical form of Newtonianism pursued by a diverse range of naturalists including Georges Buffon, Albrecht von Haller and Thomas Wright. Such naturalists aimed to develop a systematic structure for the investigation of nature that enabled the analogical extension of Newtonian principles to phenomena for which the direct application of mathematics was deemed inappropriate. This structure was understood as a *universal* natural history, one that accounts for the diversity of natural phenomena as the result of a single causal nexus.

This paper is divided into six sections. In Section 2 I provide evidence for my claim that Kant's conception of natural history builds on the 'Second Discourse' of *Histoire naturelle*, titled 'Proofs of the Theory of the Earth' (1749). Here Buffon claims that natural history properly begins with a hypothetical account of the origins in order to explain the present diversity of things. In Section 3 I suggest that Kant's reading of Buffon is mediated through Haller's methodological introduction to the German translation of *Histoire naturelle*, where Haller defends the use of hypotheses in Newtonian science. Yet in Section 4 I suggest that Kant recognized the fragmentary and incomplete character of Buffon's natural history, which left the idea of universal natural history vulnerable to attacks made by theologians. In order to rebut these attacks, Kant saw that a truly universal natural history requires a strategy of harmonizing the world system with teleology. In Section 5 I argue that he finds a way forward in Wright's theory of the Milky Way, which accounts for *our* view of the stars, including both their manifest order and beauty, as the result of a developmental history. I finish in Section 6 with some concluding remarks on the significance of Kant's text for both his own intellectual development and the future generation of naturalists who rediscovered the text.

2. Newtonian analogies

While it is clear that Kant fashioned *Universal Natural History* as a Newtonian text, there is no consensus on the sense in which it is Newtonian.[1] With this lacuna in mind, the aim of this opening section is to situate Kant's argument within the various forms of Newtonianism that developed in the mid-eighteenth century. I argue that while Kant was critical of some of Newton's key ideas, his essay is nevertheless continuous with the analogical interpretation of Newton that aimed to extend Newton's mathematical method to nature understood as a physical system.

The difficulty of understanding the early Kant as a straightforward Newtonian begins with his endorsement of Newton in the opening lines of the essay. Kant praises Newton for resolving 'the true constitution of the universe on the large scale, the laws of motion, and the internal mechanism of the orbits of all the planets' (1:229).[2] Yet in contrast to Newton's mechanics, which account for the *current* movements within the planetary system, Kant's account aims to explain how the 'ordering and arrangement of the universes [*Weltgebäude*]' are the result of a store of fundamental material that has unfolded 'gradually in a temporal sequence' (1:310). Kant develops what he calls the 'mechanical consequences of the general laws of resistance' to explain the formation of heavenly bodies out of primordial matter (1:267). To this extent he sides with those who read Newton in continuity with the Greek atomists such as Lucretius. Lucretius viewed the current arrangement of the planets as resulting

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[1] While Schönfeld (2000) presents the early Kant as a Newtonian in respect to his commitment to mechanical laws, others such as Massimi (2011) argue that Kant's use of repulsion as a fundamental Newtonian law demonstrates his commitment to the materialist tradition of Newtonianism, which drew extensively from Newton's *Opticks*. Watkins (2013, 429-430) challenges the mainstream view of the early Kant as a straightforward Newtonian by drawing attention to his many criticisms of Newton.

[2] Citations of Kant's works refer to the volume and page number of *Kants gesammelte Schriften*, Akadamie Ausgabe, and will be given in text. Translations are taken from the Cambridge editions, as noted in the Reference List.

from an initial state of chaos consisting of a diffused spread of original particles. Yet in contrast to Lucretius, Kant rejects the idea that the accumulation of those particles was accidental. Resistance is the product of two counterbalancing forces, attraction and repulsion, which causes the fine matter to whirl in vortices. Kant's claim is that the general elements of the observable universe, including the formation and regular motion of the Sun, planets, their moons, comets and even the other solar systems of the Milky Way, can all be explained by three assumptions: (1) an initial state of chaos, in which basic particles were distributed in various nebula, (2) two Newtonian principles, attraction and repulsion, and (3) the motions initiated by these matters and the states they would come to take entirely according to mechanical principles.[3]

The most striking difference between Kant's *Universal Natural History* and Newton's *Principia* is methodological. While Newton claimed to work by the application of mathematics to empirical observations, Kant presents a natural history 'in the form of a hypothesis' (1:263). His goal is to work from the present arrangement of the universe to its past through nothing other than a theory of matter. This chain of reasoning is held together by the analogical extension of Newtonian principles to events that lie outside the reach of experiment and observation. Newton had of course formulated a principle of analogy in *Principia*'s third 'Rule of Reasoning in Philosophy' to demonstrate that the naturalist has some warrant in extending her reasoning beyond possible experience. The rule states that 'The quality of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of bodies whatsoever' (Newton 1973, II 398). For example, all the bodies we encounter in experience are hard, and 'because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others' (Newton 1973, II 399). Yet while Newton accepted this inference as 'the foundation of all philosophy', for without it we would be restricted only to mathematics, he nevertheless refrained from attributing to it a universal or necessary status. Analogies for Newton are strictly hypothetical.

According to many of Newton's followers, however, analogy plays a much more central role in his method than the hypothetical extension of qualities. In his theory of gravity, for example, Newton had reasoned that just as the orbit of the moon is caused by X, so too the motion of the sea is caused by X. The capacity to construct physical analogies of the form X:Y = X:Z turns on a qualitative analogy that allows the naturalist to account for a wide range of effects by a single force. The fact that X causes both the movement of the moon and the movement of the sea is not *established* via analogy, for the connection is merely a hypothesis. Rather, the analogy guides the naturalist to a new mathematical inquiry in search for the value of X. This inquiry ultimately leads to a mathematical proof that X is in fact the cause of both effects, which Newton terms 'gravity'. Many readers of *Principia* saw that Newton's deduction of the inverse square law did not only vindicate the gravity hypothesis, it also gives the naturalist good reason to believe that the principle of analogy holds in respect to nature.

The hypothesis Kant presents in *Universal Natural History* builds on the principle of analogy, for it assumes that Newtonian principles can be extended to phenomena outside the scope of experiment and observation. The reader is invited to watch the hypothetical scene as matter unfolds

[3] Here I draw from Watkins's (2013, 430) reconstruction.

into increasing levels of organization. The protagonist is the mass of subtle particles originally diffused across celestial space, 'an infinitely rarified matter, which has accordingly infinitely little resistance' (1:115). Attraction lumps the primordial fine matter together into planets and stars. Yet by itself attraction is not sufficient to explain the formation of heavenly bodies from primordial matter. A repulsive force is required, which serves to counterbalance attraction, and make the fine matter take the whirling shape of vortices. Repulsion explains how the matter did not come together into one big lump, but whiled in vortices of different densities that became the different planets and stars we observe. The counterbalancing of attraction and repulsion accounts for the vortex mechanism, which is the key to Kant's cosmology.

Several commentators have criticized Kant's hypothetical method on the grounds that it fails to reach the deductive standard of Newtonian science. Erich Adickes (1924, I 55-56) suggests that Kant's mathematical abilities were simply too limited, meaning that a quantities procedure was possible but simply beyond Kant's reach. Fritz Krafft (2003, 179-95) blames the available empirical data, suggesting that there were insufficient resources in the mid-eighteenth century to conduct the qualitative kind of study of the universe's formation Newton had conducted in *Principia*. Yet Kant seemed unperturbed by his chosen methodology, and entertained an extremely high estimation of what analogical reasoning can achieve. In fact, he goes as far as to claim that the 'presumptions in which analogy and observation correspond to support each other completely have the same value as formal proofs' (1:255).

Kant's essay fails as a Newtonian study only if it is judged against the standard of what Wolfe terms 'experimental' Newtonianism (Schofield's 'mechanical' Newtonianism), which considers Newton's account of natural law as a form of voluntarism that removes necessity from nature.[4] On such a view natural laws are discoverable only through sensory induction. Those who went beyond what experiment and observation can deliver can only form *mere* hypotheses, which fall prey to all the gross errors of Cartesian philosophy. Newton of course provides significant grounds to adopt such a view. In the oft-cited words of the General Scholium he states that

> Hitherto we have explained the phenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power. … I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypotheses; for whatever is not deduced from the phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. (Newton 1973, II 546-547)

For the experimental Newtonians, those who violated Newton's self-limitation were seen by many as a dangerous threat to the progress of natural philosophy. As Abbé Noël Pluche explains in the late 1730s,

[4] See Schofield (1970, 15-16). For example, Pieter van Musschenbroek (1734, I 5) claimed that the idea of a fixed law is accessible only though empirical induction, and thus carries all the associated uncertainties.

> The universal capacity men are in of going further than what is sensible and useful, naturally informs them of the limits within which they ought to confine themselves. In what escapes their senses it is, that the secret of the structure, and the mystery of the operation, lies hid. Their reason may and ought to exert itself on the effects and intensions which God shews us; but never on what he conceals. … He has not taught us what the nature of heaven and earth, of metals and fluids was, as he freed us from the care of producing them. (Pluche 1740, 223-4)

In Pluche's reconstruction, Newtonianism entails that the past is hidden from us, just as the cause of gravity is hidden from celestial mechanics. For this reason Newton's *Principia* provides a mechanics of the present, and refrains from speculating about how things came to be this way. This limitation is built into Newton's theoretical program, for when force is understood as external to bodies nature has an entropic tendency. Without the constant intervention of God, 'the Bodies of the Earth, Planets, Comets, Sun, and all things in them would grow cold and freeze, and become inactive Masses' (Newton 1973, II 399-400). The fact that the universe exists at all is a result of God's creative choice: 'God in the beginning formed Matter in solid, massy, hard, impenetrable, movable Particles, of such Sizes and Figures, and with such other Properties, and in such Proportion to Space, as most conducted to the End for which he form'd them' (Newton 1973, II 400). In a cosmos that exists in a state of diminution, periodically propped-up by an intervening God, it is epistemologically unjustifiable to speculate about events that lie outside the domain of experience. For the experimental Newtonians it seemed impossible to speculate on origins and developmental histories of natural phenomena, as did Descartes and Leibniz.[5]

While the prospects of a hypothetical account of unobservable phenomena is contrary to the experimental Newtonians who held fast to Newton's *hypotheses non fingo*, Kant's attempt to extend Newton's principles to unobservable events does not break from Newtonianism. Rather, it builds on the analogical form of Newtonianism developed by a new generation of naturalists including Pierre Louis Maupertuis and Georges Buffon. In the 'Initial Discourse' of *Histoire naturelle* (1749) Buffon acknowledged that many Newtonians held to a form of voluntarism that entailed a radical scepticism about hypothesis formation.[6] Yet this form of Newtonianism is unsustainable, Buffon claims, for by confining the limits of knowledge to mathematics it denies the possibility of *physical* knowledge. In contrast, Buffon (1749, I 52) set out to establish a new method for the study of physical nature that makes us 'capable of grasping distant relationships, bringing them together, and making out of them a body of reasoned ideas.' This is achieved by 'the power of analogy.'

Buffon puts this new method to use in the 'Second Discourse' of *Histoire naturelle* entitled 'Proofs of the Theory of the Earth'. He begins by separating two kinds of natural history: a general,

[5] Descartes (1985, 132) for example uses natural laws derived from God's perfection to show how, 'in consequence of those laws, the greater part of the chaos had to become disposed and arranged in a certain way which made it resemble our heavens, and how at the same time, some of its parts had to form an earth, some planets and comets, and others a sun and fixed stars.' Yet he does not account for *how* the planets, comets and sun came to be.

[6] There he stated that his intention is to assist the reader to 'more readily specify the great difference that exists between an hypothesis, in which there is nothing but possibilities, and a theory based on facts.' While his own theory is certainly hypothetical, it proceeds via a probabilistic method that he claims to be capable of proving speculative claims beyond reasonable doubt.

physical natural history which provides the 'general history of the earth', and a particular, classificatory natural history concerned with the earth's 'productions' (Buffon 1812a, 1). The idea is that the categories used in classification should not be taken from the sphere of logic and applied to the products of nature from the top down, as it were, but rather derived from the knowledge of physical nature from the bottom up. The details of particular facts, which normally make up the content of natural histories, 'are not, perhaps, so much the objects of natural history [properly understood], as general deductions from the observations that have been made upon the different materials of which the earth itself is composed.' Buffon's (1812a, 2) radical proposal is that 'all physical knowledge, where system is excluded, [is] part of the history of Nature.' The reason that a *physical* theory of the universe has not been established is that so much of it lies beyond our experience, making it difficult for reason to avoid the pitfalls of fancy. Nevertheless, Buffon (1812b, 61) proposes to take up the 'hypothetical manner' of physics to develop 'a physical history of its real condition.' An early reviewer of *Histoire naturelle* writing for *Bibliothèque raisonée* was aghast at such a proposal, and summarized Buffon's scandalous project as follows: '[in Buffon's natural history] Nature enjoys the right of forming herself, of organizing herself, and of passing freely from the inanimate state to that of a plant, or that of an animal' (Anon. 1981, 270).

3. Haller and hypotheses

Kant was clearly impressed by Buffon's arguments in favour of a general, physical natural history that would account for the present diversity of nature's products before turning to the task of classification. Yet as we will see, he nevertheless found significant gaps in Buffon's actual account, gaps that were exploited by Buffon's theologically motivated reviewers. In this section I suggest that Kant found a productive way to read Buffon's proposal via Haller's methodological reflections on *Historie naturelle*, which aimed to soften those who were sceptical of Buffon on theological grounds.

Within a year of its original publication, the first volume of *Historie naturelle* was translated into German by Abraham Kästner with the title *Allgemeine Historie der Natur* (Buffon 1750-52). Anticipating the controversial reception of the project, Kästner commissioned the help of Haller, by then one of the most respected naturalists in Europe, to provide an introductory preface. While Haller (1981, 307) warns the reader that Buffon 'always goes somewhat further than his information, experiments, and insight', and thus that extreme caution should be exercised in accepting his views, his aim is to vindicate Buffon's use of hypotheses in legitimately Newtonian science. The true merit of Buffon's project, Haller (1981, 306) claims, lies in its capacity to open new and uncharted terrain for experimental philosophy.

Haller's call to carefully consider Buffon's project without rushing to one of the extremes of the understanding, and Kästner's rendering of *Histoire naturelle* as a *general* (*allgemein*) natural history, invite the reader to consider Buffon's project as an extension of Newton's account of gravitational force rather than as a break from Newtonianism. In Haller's representation, Buffon's goal is to base the descriptive part of natural history on a universal theory of nature understood as a complete physical system, applying to physics what Newton had done for mathematics. Buffon originally framed his hypothesis as follows:

> Could one not imagine with some sort of probability that a comet, falling on to the surface of the sun, could have displaced that star, and that several parts of it would have been separated, to which would have been communicated a movement of impulsion in the same direction by the same impact [*dans le meme sens, par un meme choc*], so that the planets would have belonged formerly to the body of the sun, and been detached from it by a force of impulsion common to them all, a force which they conserve to this day? (Buffon 1812b, 64-65)[7]

As evidenced in its early reviews, readers of *Histoire naturelle* found this hypothesis difficult to stomach. How could such a blatantly speculative thesis ever be vindicated? Anticipating such an attack, Buffon spent considerable time in 'Proofs of the Theory of the Earth' criticizing natural theologians such as William Whiston, Thomas Burnet and John Woodward, who aimed to use mechanistic physics to defend the scriptural creation narrative. In *The Natural History of the Earth* (1726), for example, Woodward (1726, 29) insisted on 'the exact Agreement betwixt Nature and Holy Writ from Observations, and Facts at this time demonstrable in the whole terraquous Globe.' In his examination of Whiston's cosmology, Buffon concludes with the following:

> Wherever men are so presumptuous as to attempt a physical explanation of theological truths; whether they allow themselves to interpret the sacred text by views purely human; whenever they reason concerning the will of the Deity, and the execution of his decrees; they must necessarily involve themselves in obscurity, and tumble into a chaos of confusion, like the author of this whimsical system. (Buffon 1812b, 109)

In Buffon's view, the mechanistic interpretation of Newton leads to far more speculation than his own materialist hypothesis. The natural theologians were unable to provide a cosmology fitting with Newtonianism, let alone to explain the compatibility of Newtonian principles with an interventionist God. Buffon instead places himself much closer to the celestial dynamics of Leibniz by fusing Newtonian mechanics with a dynamical theory of matter. Phillip Sloan (1981, 131) explains that, in agreement with Leibniz, 'Buffon's world is autonomous since its first beginnings in the chance collision of a comet with the sun.' The autonomy of such a dynamical system, according to Sloan, enables Buffon to utilize 'a Newtonian methodological principle with greater consistency than Newton himself had done', for it extends Newton's mechanics to moments of world-time beyond possible experience. This Newtonian principle is the principle of analogy, whereby the properties that are discovered to hold between bodies available to observation, such as attraction and repulsion, are attributed to *all* bodies, including those extant at the beginning of time. Following Hales' method in *Vegetable Staticks*, which had applied Newtonian analogy to plant physics, Buffon turns Newton's principle of analogy into one of cosmological reasoning. He applies the apparent natural causes of events that we *can* observe in the present to events that occurred in the remote past. Leibniz' account of

[7] Here I cite Sloan's translation of the text, for it seems that Smellie has missed out the crucial phrase regarding the communication of force. Following this passage Buffon inserted a plate that graphically depicts God moving a comet into the sun.

the origins of the planets would have been 'more comprehensive, and more consonant to probability', Buffon (1812b, 65) claims, if he had provided a causal account of how they originally split from the sun, rather than merely positing that they were themselves formerly suns.

While Buffon defended some aspects of Leibniz' cosmology in order to remove the need for divine tinkering in the Newtonian system, his universal natural history nevertheless presented a degenerating and ultimately dying system, one that is wondrous now but losing its momentum and life-sustaining power. The cost of removing God's direct role, it would seem, is a universe with no teleological structure. For this reason the reviewer for *Nouvelles ecclésiastiques* attacked *Histoire naturelle* as a work filled with 'venom' that expounds an unscriptural and 'pernicious system' (Roche 1981, 237-8).[8] Buffon's comet hypothesis replaces the theoretical certainty guaranteed by a purposeful creator with a probabilistic calculus, thereby introducing skepticism into both 'religion and all the human sciences' and surrendering all to 'incertitude' (Roche 1981, 241). Moreover, the reviewer found *Histoire naturelle* to be deeply unscriptural, for not only does it place humans on the same level as the animals but its account of geological formation, which involves the formation of landmasses and mountains from the sea, implies 'a world far older than Moses made it out to be' (Roche 1981, 243).

Haller knew well that Buffon's use of hypothetical reasoning controversially departed from the Newton of the General Scholium. This, combined with his attack on natural theology, had earned Buffon a public reprimand from the Sorbonne's Faculty of Theology.[9] However, where Buffon sought to antagonise, Haller instead identifies the common ground held between the experimental and analogical interpretations of Newtonianism. *Both* interpretations agree that the castle building practiced by Cartesian natural philosophers overstretches the understanding. And yet Haller contends that those who seek to preserve themselves from *all* error, and thus become skeptics about all matters that cannot be proved via deduction, are equally misguided. The 'practice of rejecting all hypothesis', he states, 'can become more detrimental to mankind than the dreams of the philosophers of the schools could ever have been' (Haller 1981, 298). Haller (1981, 299) notes that not even Newton, the 'destroyer of arbitrary conjectures', has been able to do without hypotheses: 'Was his ether the medium of light, sound, sensation and elasticity, not a hypothesis?' Haller's reference to Newton's ether is illuminating, for it shows that the Newtonian context in which he seeks to defend Buffon consisted of a much broader view of Newton's work than *Principia*. Haller's proposal is that Newton's work, taken as a whole, paves the way for the *correct* use of hypothesis making. If such an intellectual giant found it appropriate to use 'the probable as currency', then it must not be entirely without value (Haller 1981, 299). So much of nature is unknown to us that without hypothesizing – without trading in the currency of the probable – 'we must remain silent on almost all of natural philosophy.' Rather than constructing an aggregate of independent facts without connection, hypotheses allow us to 'construct a building

[8] The review was probably written by the editor, Fontaine de la Roche.

[9] In 1751 the Faculty of Theology at the Sorbonne had charged Buffon for establishing 'principles and maxims which are not in conformity with those of religion.' They laid down fourteen 'propositions extracted from a work entitled *Histoire naturelle* which have appeared reprehensible.' The most important for our present interest is Proposition IX: 'Mathematical evidence and physical certitude are, then, the only two aspects under which we ought to consider truth. Insofar as it is distanced from one or the other, it is no more than verisimilitude and probability' (The Deputies and Syndic of the Faculty of Theology of Paris 1981, 285-287).

instead of a ruin.' Haller clarifies the epistemic status of hypotheses as dynamic guiding principles: they do not utter propositions with a truth value but rather lead to the discovery of truth.

4. A universal natural history

Kant's *Universal Natural History* builds on Haller's cautious endorsement of *Histoire naturalle* in several important ways. Like Haller, Kant identified the significance of Buffon's project in its analogical interpretation of Newtonianism, which aims to complete the Newtonian project by providing an exhaustive, physical system of nature. Kant seems to have fashioned the title of his book after Kästner's rending of *Histoire naturelle* to indicate his intention to provide an *allgemein* account of nature, as did Buffon. However, while Kant saw that Buffon's hypothesis opened a new and exciting field of inquiry, as Haller noted in his preface, he also recognised that it consists of fragmentary reflections. The fragmentation begins with the comet thesis. If the planetary system began with a comet colliding with the sun, how did the sun and comet emerge from the chaotic nebula? And how did this accidental collision result in the well-ordered system we see today? In this section my aim is to show that Kant aimed to complete the physical system by harmonizing planetary physics with teleology. This requires a new theory of matter capable of grounding a truly universal programme.

In *Universal Natural History* Kant acknowledges his debt to Buffon as follows:

> what shows the natural formation of the heavenly spheres out of the basic material that was originally dispersed in the space of the heavens that are now empty as clearly as anything else is the correspondence I borrow from Herr von Buffon which, however, in his theory does not have by far the usefulness that it has in ours. (1:345)

In Kant's view, the basic problem with Buffon's cosmogony is not so much the comet thesis (Kant after all praised Buffon's idea of a physical origin) as the attribution of the ordered arrangements of the planetary masses to chance. It is no wonder that *Histoire naturelle* caught the critical eye of the theologians! Anticipating the possible response of the Königsberg theologians to his own natural history, Kant begins with greater sensitivity than Buffon. His strategy, rather than attacking the natural theologians, is to beat them at their own game. Following Haller's idea of two extremes of the understanding, Kant prefaces his essay by identifying two kinds of skeptics: the theologians, for whom the attempt to explain the origin of the universe and its subsequent formation by natural laws is a dangerous form of atheism, and the experimental Newtonians, who saw such an attempt as a pernicious form of speculation. Kant formulates the theological objection as follows:

> If the universe [*Weltbau*] with all its order and beauty is merely an effect of matter left to its general laws of motion, if the blind mechanism of the powers of nature knows how to develop so magnificently and to such perfection all of its own accord: then the proof of the divine Author, which one derives from the sight of the beauty of the universe, is entirely stripped of its power, nature is sufficient in itself, divine government is superfluous. (1:222)

Kant's notion of 'blind mechanism' is the key to his portrayal of the theological objection. Mechanical philosophy seems to remove all sense of purpose from nature, and with it the connection between our experience of beauty and a divine architect. This caricature was certainly true of Buffon. Yet for Kant this objection does require one to develop an opposed conception of a 'designed' mechanism. Kant was strongly opposed to those who attempted to save theology from the encroachment of natural philosophy by finding evidence of design in every trace of usefulness in nature's products. On this point Christian Wolff was the foremost offender, locating design in any natural phenomenon that bares the least resemblance of finality.[10] For Kant, Wolff's physicotheology inhibits natural science from discovering the mechanism responsible for nature's order. In contrast to both the theologians and the skeptics, Kant develops a mechanistic programme that fuses mechanism and teleology into a single framework. Kant's goal is to develop a *mechanical* teleology, one that conforms to the principles of Newtonian science. Final means must be congruous with the physical processes of nature without requiring appeal to God in nature's causal nexus.

Kant had already opposed the idea of divine interference in his early essays on mechanics. In *Thoughts on the True Estimation of Living Forces* (1746) he presented a 'metaphysical' account of force in which he affirms Leibniz's account of bodies as possessive of an essential, active force (*vis activa*). He begins by criticizing the experimental philosophers who claim to 'look no further than the senses teach' (1:17). This goal changes what it means to give an explanation from Aristotelian entelechy, which accounts for force as an internal and goal-oriented principle of change, to a mathematically demonstrable theorem, which accounts for movement according to blind forces operating upon inert matter. Observation, Kant notes, yields an account of 'force as something communicated solely and entirely from the outside, something the body does not have when it is at rest' (1:17). The result is an entropic system in which God must constantly add motion to prevent its store from being depleted with time, thus maintaining the universe in its present state.

Kant claims that in contrast to experimental philosophy (and 'luckily' for reason) Leibniz properly understood Aristotle's entelechy, allowing him 'to teach that an essential force inheres in a body and belongs to it even prior to extension' (1:17). Since force is prior to extension, matter and space are not primitive but emerge through active processes. Kant, however, was critical of Leibniz's theory of pre-established harmony, which accounts for interaction as an emergent property rather than an intrinsic part of nature. As he later explains in *New Elucidation of the First Principles of Metaphysical Cognition* (1755), while Leibniz rightly acknowledges the agreement between substances he does not allow for 'their reciprocal dependency on each other' (1:415). In this sense he was closer to the physical influx theory defended by Christian Wolff and Martin Knutzen, which accepts a physical transfer of properties between substances. Yet he also found problems with this view. Physical influx removes the harmony of forces, and thus begs the question of teleological order Kant was attempting to explain. To maintain Leibniz's conception of a harmonious system, and yet provide an explanation for harmony in terms of physical properties, Kant accounts for the action of primitive forces as affecting

[10] In *Vernünfftige Gedancken Von den Absichten Der natürlichen Dinge* (*Deutsche Teleologie*) Wolff (1724) speculates about the existence of natural products according to their role as final means. For example, the stars are explained according to their role in enabling nocturnal navigation (§33) and the sun according to the aid it provides to human industry (§47).

other forces. As Schönfeld (2006a, 37) explains, Kant's early theory of forces is 'dynamic' to the extent that it begins with force as original presence, which would not exist if it did not act.[11] When a force acts it 'spreads its self out' (*ausbreiten*), thereby becoming 'out-stretching' or 'extended' (*Ausdehnung*) (1:24). Kant explains as follows:

> It is easy to show that there would be no space and no extension if substances had no force to act external to themselves. For without this force there is no connection, without connection, no order, and, finally, without order, no space. (1:23)

The activity of force extends space, and by doing so it generates order and connection. From this dynamical account of matter Kant reasons that force creates the world, and thus everything in it. Citing Wolff, Kant defines a world as 'the series of all simultaneously and successively existing contingent things that are connected with each other', a *nexus rerum* (1:23). The idea is that relations are constitutive of a referential frame, and create the possibility of there being locations within it. Space and time themselves are dependent on the activity of the basic matter that constitutes nature.

Kant's dynamical account of space stands radically opposed to the empty space assumed by the experimental Newtonians. Newton's empty space is an abstraction from the present state of the universe, for it claims priority over the external operation of force upon matter. Thus construed, the orbits of the planets are simply 'a consequence of the agreement they all must have had with the material cause by which they were set into motion' (1:261-2). In Kant's view, the priority of space over force meant that Newton could not envisage a material cause for the arrangement of the planetary system, and thus had no alternative but to appeal to 'the direct hand of God' (1:262). Kant seems to be referring to the General Scholium, where Newton (1973, II 544) states that 'it is not to be conceived that mere mechanical causes could give birth to so many regular motions.' In contrast to a universally mechanical system, Newton claims that

> This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being. And if the fixed stars are the centres of other like systems, these, being formed by the like wise counsel, must be all subject to the dominion of One … and lest the systems of the fixed stars should, by their gravity, fall on each other, he hath placed those systems at immense distances from one another. (Newton 1973, II 544)

Newton's (1973, II 546) reasoning is that the present diversity of things, and the harmony between qualities and environment, could not arise apart from the 'ideas and will of a Being necessarily existing.'[12] In the *Opticks* he similarly conceded that the elliptical movement of the planets is inexplicable according to natural philosophy. If universal gravitation were the only law responsible for

[11] My account of *New Elucidation* draws from Schönfeld's (2006a) reconstruction.

[12] He states that while the planets and comets 'continue in their orbits by the mere laws of gravity, they could by no means have at first derived the regular position of the orbits themselves from those laws' (Newton 1973, II 543).

the arrangement of the planetary orbits, then the orbits would be random. However, they are clustered around one plane, and orbit the sun in the same direction. Because Newton (1721, 402) could not envisage a mechanical cause for this pattern he concluded that ‘such a wonderful Uniformity in the Planetary System must be allowed the Effect of Choice.’

Thus *both* Buffon and Newton end up calling on an arbitrary cause (chance and choice) to account for the universe’s origins. While Buffon rejected teleology altogether, Newtonian teleology in the form of God’s ideas and will works *against* the mechanical order. For Kant, this is nothing less than despair at the power of reason to live up to its vocation. In response, Kant argues that the very same difficulty that ‘deprived Newton of hope of understanding the orbital forces imparted to the heavenly bodies … is the source of the doctrine we have presented’ (1:339). What Newton could achieve only in mathematics Kant, following and yet superseding Buffon, proposes to do in physics, thereby bringing to physical science the ‘completeness to which Newton raised its mathematical half’ (1:230).

Kant’s historical account of nature’s self-organisation entails a radically different conception of creation to the theologians. The theologians separate the laws of motion, which constitute the world system, from the action of an omnipotent God. Kant, on the other hand, claims that creation ‘is not the work of one moment’ (1:314). After the creative process ‘has made a beginning with the production of an infinity of substances and matter’, he states, ‘it is effective throughout the entire sequence of eternity with ever increasing degrees of fruitfulness’ (1:314). Historical development is thus maximally robust, constituting the ongoing creation of the entire universe. God does not create *into* time and space in a single moment, as Newton assumed. The domains of time and space are rather the properties of matter that unfold in unbroken systematic connection. Attraction ‘is precisely that universal relationship that unites the parts of nature in one space’, uniting all particles together in ‘the great chain of all nature [*die große Kette der gesammten Natur*]’ (1:308). Kant claims that, given the system advanced in *Universal Natural History*, we can ‘now reconcile a mechanical doctrine with the teaching of intentions in such a way that what the highest wisdom itself designed has been delegated for implementation to coarse matter and the regiment of providence to nature left to its own devices’ (1:363). The highest wisdom is not directly responsible for the design we discover in nature. Rather, it is responsible for an even more awe-inspiring act of creativity: the creation of formless matter capable of giving shape to itself.

5. Wright and physical teleology

Yet Kant’s attempt to integrate continuous development into the static programme of eighteenth century celestial mechanics opened a significant problem, for the idea of a developing system contains a contradiction. If the system of nature is ordained by God then it must be perfect. Yet any alteration in a perfect system implies a departure from perfection (Schaffer 1978, 180). It is for this reason that many experimental Newtonians kept a hard distinction between celestial mechanics and God’s action: God’s perfection is protected from the transience of the world order. How could such a contradiction be resolved? My aim in this final section is to show that in contrast to the experimental Newtonians, who held onto an external conception teleology, and in contrast to Buffon, who rejected teleology, Kant followed Thomas Wright in examining the world system from a hypothetical standpoint to show that development could be reconciled with the stability of the universal order.

In the Preface to *Universal Natural History* Kant explains that his idea of cosmological development builds on the insights of Wright's 'An Original Theory or New Hypothesis of the Universe' (1750), a report of which appeared in German in the Hamburg journal *Freye Urtheile und Nachrichten* in January 1751.[13] In this essay Wright described the celestial formations in terms of 'shells' of stars, systems that were each organised around a divine centre of attraction. The stars of each shell orbit around the centre in a vortex formation through a combination of attractive and repulsive forces. The apparent chaos of stars we call the Milky Way could then be explained according to the effect of the observer looking from within our shell along one of its tangent planes (Schaffer 1978, 181). Wright emphasised the developmental aspects of cosmology, and attributed changes in the system due to the activity of fire. Fire, for Wright, implies both constant change *and* self-maintenance.

While he did not suggest that the universe's structure evolved from a more primitive state, Wright broke from standard cosmologies of his time by locating the activity that forms and replenishes the cosmos within matter. God's presence, Wright argued, is manifest through God's 'power' and 'wisdom', meaning that one does not require miracles or divine intervention to account for God's role in creation. From our finite vantage on earth we might *think* that change, perturbation and decay signals a system in entropy. Thus we reason that God *must* intervene to prevent the otherwise inevitable collapse. Yet Wright insists that the problem does not lie with the creation but with our understanding. Just as the chaos of stars we call the Milky Way becomes a perfectly self-organising system when rightly understood, so too the universe understood as a whole. Thus Wright aimed to rationalize development and decay as part of a perfect world. He criticised Newton's *Principia* for failing to infer the divine attributes from the perfection of the world system: Newton had 'contented him self with enumerating some of the principle Divine Attributes and leaving us in all things else to be lost in a kind of infinite common wealth of nature' (Wright 1837, 18).

According to Kant, Wright's ideas were the original source that gave him 'cause to regard the fixed stars not as a scattered milling mass without any visible order' but rather as a 'a systematic constitution' (1:231). For Wright, the key to this discovery begins with the shape of the Milky Way, which guides a thought experiment about the role of attractive and repulsive force in the formation of vortices. The apparent chaos of the Milky Way is an effect of viewing a disk-shaped vortex along the plane of the disk. Kant generalises beyond Wright's Milky Way hypothesis to claim that other nebulae are also similar disk-shaped galaxies viewed at different angles, building on Maupertuis' account of the starry nebula in *Discours sur la figure des astres* (1742). The competing mechanical account of creation advanced by Descartes (1983, III 48-54) relied on the theory of vortices in which celestial movement supposedly follows stratified bands of secondary or primary matter left over from the fracture of larger elements. This theory had been emphatically rejected by the Newtonians for having

[13] Schaffer (1978, 189) argues that Wright's essay was reported quite badly, for Kant interpreted Wright as suggesting that the Milky Way was an effect of an observer looking along the line of a thin layer of stars orbiting a center on a single axis. This is more in line with Maupertuis' elliptical account of starry nebulae.

no possible experimental vindication. Even Wright, at least in his 1750 essay,[14] refrained from generalising from his mechanical account of vortices to a speculative thesis concerning their role in creation. Wright (1837, 12) continually stressed the limits of natural philosophy: 'how the heavenly bodies were made, when they were made, and what they are made of, … seems to our present sight not to be within the reach of human philosophy.'

Despite Wright's hesitancy, Kant saw that his system placed the original formation of the vortices in the physical sphere of creation. Kant explains that while he has 'imitated' Wright's model he has also 'explained it further' (1:232), combining Wright's self-organising shells with Maupertuis' account of galaxies as open ellipses to describe the hierarchical order of the entire cosmos. The key for Kant was a physical account of the formation of vortices that extends attraction to past events to explain the condensation of the galactic cloud and repulsion to set it spinning (1:250). What seems to us as an expansive chaos of the heavens is in fact, once properly reconstructed from a standpoint *outside* the Milky Way, the self-organisation of a series of clustered galaxies, united as systems within a system. Development is permitted for Kant so long as the *unity* of the system as a whole is preserved. Systematic order can emerge from mechanical principles alone, provided one begins with the right theory of matter.

Wright's account of the self-maintaining system of the Milky Way enabled Kant to explain the 'distinct characteristics of transience' in the physical world (1:326). Kant proposes a law of nature: everything that has a beginning is constantly moving toward its end (1:353). The outworking of this principle is seen in Chapter 7, the 'Universal history and theory of the sun', where Kant fuses Wright's theory of self-organising shells of stars with Hales' experiments on light in *Vegetable Staticks*. Hales had made use of both attractive and repulsive forces to explain vegetable, animal and mineral fermentation process. For Kant, his experiments reveal that 'all flames always devour much air and there is no doubt that the elastic force [*Federkraft*] of the liquid element of air that surrounds the Sun must suffer over time a not inconsiderable disadvantage thereby.' Of course, the constancy of the sun, despite the ferocity with which it burns, means that we must conceive of it in some way as a self-sustaining entity. Yet Kant notes that if we extend what 'Herr Hales has confirmed through careful experiments about the action of flame in our atmosphere', then the elasticity of the sun's atmosphere must eventually be destroyed (1:326). This means that the sun must, eventually, extinguish itself.

Kant's extension of Hales' experiments to the physical system of the universe allowed him to solve the problem of development, for it justifies the appearance of transient phenomena such as the sun through a greater perfection in which they participate. He states that while

> perfection of all world-orders is threatened by inevitable destruction, we shall find no difficulty in the aforementioned law of their demise by means of the tendency of the mechanical arrangement, which, however, becomes acceptable, principally because it bears within itself the seed of renewal even in being conjoined with chaos. (1:327)

[14] In his 1755 essay *Second or singular thoughts upon the theory of the universe* Wright (1968) uses fire as the basis for God's action, which conserves while also transforming the cosmos.

Kant's organic metaphor is important to note. Even in 'the most loathsome state of its disorder', he exclaims, the destruction and chaos of the cosmos 'brings about the beauty of the world and the benefit of the creatures' (1:328). To grasp destruction and chaos within the context of beauty and benefit, our examination of nature's self-organization requires us to adopt the abstract, disinterested standpoint developed by Wright. Our first response to the sheer magnitude and infinite diversity of creation is 'silent astonishment', for it causes us to feel our tiny state in the vastness of nature. Yet it leads to a deeper, intellectual pleasure, for it 'captures our understanding when it contemplates how so much splendour, so much grandeur flows from a single universal rule with an eternal and right order' (1:306). It is only the delight of the understanding that can vindicate the apparent transience of natural products – even those that threaten our very existence – for it results from our cognition of an end beyond ourselves, the great system of nature. This is not some kind of reflective enjoyment that depends *on us*. Kant offers a thoroughly realist aesthetics that provides further evidence for his cosmological hypothesis: 'the formation, the shape, the beauty and perfection are relationships of the building blocks [*Grundstücke*] and of the substances that constitute the material of the universe' (1:310). Here Kant weaves matter and form so closely together that beauty simply *is* the property of systematic order manifest in the interaction of nature's building blocks. He concludes in exhortation at the sheer exuberance of creation, which includes and even vindicates destruction:

> Nature shows its bounty in a kind of extravagance, which, while some parts pay their tribute to transience, maintains itself regardless through countless new creations in the whole extent of its perfections. What countless mass of flowers and insects does not a single cold day destroy; but how little do we miss them even though they are splendid artworks of nature and proofs of divine omnipotence! (1:318)

Kant's account of nature's self-maintenance through destruction is captured by his famous metaphor of the 'phoenix of nature' (1:321). In stark contrast to the experimental Newtonians, who understand beauty as the rupture of the property-less order by God, Kant insists that nature is *bound* to perfection, which means that it 'must necessarily bring forth beautiful combinations' (1:228). Kant returns to this argument in Chapter 8, which offers a general proof for his mechanical doctrine of the universe. Again he examines the two extremes identified in the Preface, the theologians and the experimental Newtonians. Yet here he shows that both views are essentially the same, for both accept the 'almost universal prejudice' that nature is unable 'to produce anything orderly through its universal laws just as though it would be disputing God's governance of the world if one were to seek original formations in the forces of nature' (1:332). Kant argues that the separation of order from universal law is profoundly unscientific, for 'any useful correspondences that shine forth in the constitution of nature points to the direct hand of God', thereby turning 'the whole of nature into miracles' (1:332-3). This position effectively destroys nature, understood as a continuous causal nexus, replacing it with 'a god in the machine bringing about the changes in the world' (1:333).

Kant's summation and proof of his hypothesis in Chapter 8 suggests that his primary goal in *Universal Natural History* is to show that a universal conception of natural history can provide a sure ground for physics without discounting teleology. If one considers how nature could produce so much beauty and order if left to itself, 'then nature will appear to us more dignified than it is commonly regarded and one will expect from its unfolding nothing but correspondence, nothing but order' (1:332). God is no longer required to keep nature in operation, and yet beauty and order continue to elicit our respect for a cosmic engineer. Thus Kant's strategy to remove the flaws from Buffon's universal conception of natural history takes the form of a Leibnizian view of the present arrangement as the best of all possible worlds. The result, however, is profoundly unique. Leibniz ascribed mechanics to phenomena in the shape of law, and teleology to the substances in terms of entelechies. Kant on the other hand advances an *immanent* teleology that collapses Leibniz' separation of the two orders of nature into a universal, unfolding domain manifest in its tireless activity.

6. Concluding remarks

Locating Kant's *Universal Natural History* within debates over the limits and scope of Newtonian science in the eighteenth century provides a richer understanding of its historical significance. Scholars have often struggled to articulate the sense in which Kant's early essay is Newtonian, which has led to the view that it is an individual and progressive text that is more resonant with nineteenth century *Naturphilosophie* – and even with modern physics – than with Newtonian science in the 1750s. Yet seen against the backdrop of the divergent interpretations of Newtonianism that developed during the eighteenth century, it becomes evident that while Kant's essay was part of the free-thinking and anti-clerical movement associated with Buffon it does not break from the methodological rules of Newtonianism. Rather, it develops the analogical interpretation of Newton that transformed his mechanics into a physical system of nature. The achievement of Kant's *Universal Natural History* is to transform what it means to develop a natural history from constructing a logical system of classification to explaining the physical diversity of natural products according to laws.

This study invites further research into the extent to which analogical Newtonianism shaped Kant's later work, especially his published essays on natural history in the 1770s and 1780s and his critical philosophy. Mapping out a *universal* natural history, one that enables the naturalist to extend Newton's method via the principle of analogy, is a theme that continues throughout Kant's writings. In *Universal Natural History* Kant builds on Buffon, Haller and Wright to show that reason is capable of providing an imaginary standpoint, what Kant will call a *focus imaginarius* in *Critique of Pure Reason* (A644/B672), by which we can extend the unity that is essential to reason but indifferent to the understanding by constructing a physical system of nature. It is precisely because the understanding cannot cognise the order of the Milky Way or the beauty of destruction that reason must adopt a hypothetical standpoint from which the cognitions of the understanding can find their systematic ground. While Copernicus, Kepler and Newton demonstrated that it is possible to abstract to an imaginary standpoint outside the galaxy to represent the celestial system in space, and Wright demonstrated that it is possible to extend even further to see that, from a vantage outside the Milky Way, we can represent the celestial system is also part of a greater system, Kant saw that Buffon demonstrated that we can project in *time* to construct an ordered system of which *we* are a product. Of course, Kant's later notion of a *focus imaginarius* is an ideal point that allows us to reflect, with the use of reason's demands, on questions that the understanding cannot answer. Yet before concluding that the difference between *Universal Natural History* and the critical philosophy is that Kant drops a constitutive account of nature understood as a system, we do well to remember that Kant's essay merely presents a hypothesis. The question Kant later takes up in the critical philosophy is what the possibility of cosmological reasoning, such as that presented in *Universal Natural History*, tells us about cognition; what is it that enables us to construct hypotheses about regions of nature we have not experienced? The answer requires a critical reappraisal of analogy.

One change that certainly does occur in the critical philosophy is that Kant denies the possibility of vindicating hypotheses about physical nature.[15] While Kant will claim in the B Introduction to the first *Critique* that we can authenticate hypotheses about the transcendental structure of cognition, for we can come prove them apodictically, in the Transcendental Dialectic he argues that hypotheses formulated about the products of nature as we find them converge asymptotically with nature (A663/B691). Our knowledge of physical nature cannot reach the certainty he had hoped for in *Universal Natural History*. For many of Kant's later readers, however, his early attempt to reenergise teleological language by invoking the properties of matter provided the scaffolding for a new, speculative physics, and with it a new set of criteria for valid proofs. In a brief obituary to Kant in 1804 Schelling (1860, VI 7) praised *Universal Natural History* as a work that soars above all other cosmologies written since, for, unlike those Newtonians who require recourse to divine tinkering to maintain the cosmological system, Kant 'sought the reasons and determinations of the world system and its movement in the field of matter and natural forces.' In contrast to the experimental Newtonians, who assume a fundamental split between natural law and purposive design, Schelling saw that the young Kant located the ontogeny of the cosmos *within* the domain of nature as a productive sphere. A 'true system of natural history', he states, 'has for its object not the *products* of Nature but *Nature itself*' (Schelling 2004, 218).

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[15] See 'Pure Reason in Regard to Hypotheses' in the Doctrine of Method, especially A769/B797. Kant argues that creative power of imagination, which enables us to go beyond experience, can be harnessed to extend our knowledge of nature hypothetically.

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Highlights:

- Contextualises Kant’s *Universal Natural History* (1755) within the various forms of Newtonianism developed in the eighteenth century
- Examines the influence of Buffon’s universal conception of natural history on the early Kant
- Concludes that Kant’s essay contributes to the transformation of natural history from a logical system of classification to an explanation for the physical diversity of natural products according to laws