



INTRODUCTION

Kant's Ongoing Relevance for Philosophy of Science

Andrew Jones¹ and Andrew Cooper²

¹University of Exeter and ²University of Warwick

Corresponding author: Andrew Jones; Email: aj359@exeter.ac.uk

Abstract

In this introductory article we reconstruct several broad developments in the scholarship on Kant's theory of natural science with a particular focus on the Anglophone context over the past half-century. Our goal is to illuminate the co-development of Kant scholarship and the philosophy of science during this period and to identify points of influence in both directions. In section 2 we present an overview of the scholarship on Kant's account of natural laws. In section 3 we survey the diverse interpretations of Kant's views on biology and consider recent appeals to Kant by philosophers of biology. In section 4 we explore several recent developments in philosophy of science that have potential synergies with Kant scholarship. Our aim is not simply to establish that Kant's philosophy can have relevance for philosophy of science but also to point out where it has been and continues to be relevant. Appreciating this relevance, we suggest, can help identify productive lines of inquiry for Kant studies.

Keywords: Kant; natural science; philosophy of science; biology; laws

1. Introduction

Over the past fifty years, there has been a flood of interest in Kant's relation to natural science in Anglophone scholarship. Since the pioneering work of Peter Plaass ([1965] 1994), Gerd Buchdahl (1969), Gordon Brittan (1978) and Robert Butts (1986), scholarship has expanded from Kant's general theory of science (Watkins 2001) to his engagement with particular sciences, including physics (Berg 2014; Friedman 1992, 2013), chemistry (McNulty 2015) and biology (Goy and Watkins 2014; Huneman 2007). In the past decade, scholars have given special attention to the role of laws in Kant's philosophy (Massimi and Breitenbach 2017; Watkins 2019).

This special issue brings together emerging and established scholars working on Kant's theory of natural science to take stock of past developments and to anticipate future work. Our overarching thesis is that examining the historical and conceptual connections between Kant's philosophy and philosophy of science can help us to frame foundational but often overlooked questions, including the human-centred character of scientific inquiry, the assumptions underpinning scientific research and the end or goal of science. In this introductory article we reconstruct several broad

developments in the scholarship on Kant's theory of natural science with a particular focus on Anglophone scholarship over the past half-century. Our goal is to illuminate the co-development of Kant scholarship and the philosophy of science during this period and to examine points of influence in both directions. While we argue that the pressing themes in Kant studies often track broader debates in philosophy of science, we also identify several ways that Kant's philosophy has impacted philosophers of science – whether they have understood Kant correctly or not.

In section 2 we present an overview of the scholarship on Kant's account of natural laws over the past fifty years. In section 3 we build on this history to identify the importance of Kant's philosophy for recent developments in philosophy of biology. In section 4 we explore several recent developments in philosophy of science that have potential synergies with Kant scholarship, including some areas that are not currently associated with Kant's philosophy. Our aim is not simply to establish that Kant's philosophy can have relevance for philosophy of science but also to point out where it has been and continues to be relevant. Appreciating this relevance, we suggest, can help identify productive lines of inquiry for Kant studies.

2. Kant and natural laws

Since its initial publication, Kant's critical philosophy has resurfaced at several decisive moments in the history of philosophy of science. In the nineteenth and early twentieth centuries, several philosophers of science – including William Whewell, Ernst Cassirer, Arthur Lovejoy and Hans Reichenbach – discovered in Kant a way of articulating both the general conditions of scientific knowledge and the autonomy of particular domains of scientific research. Yet if John Stuart Mill's victory over Whewell is anything to go by, or the ascendancy of logical positivism over Neokantianism, it seems that Kant's synthetic *a priori* has not aged well. In the mid-twentieth century, the unity of science hypothesis rejected Kant's attempt to retain a place for modality (causation, dispositions, counterfactual conditionals, etc.) in nature,¹ and in the late twentieth century the idea of universal natural laws once again came under fire.² The negative view of lawfulness is reflected within Kant scholarship itself. Some scholars have argued that Kant's derivation of the properties of matter in *Metaphysical Foundations of Natural Science* is irredeemably tied to Newtonianism (Heidegger 1967: 126), while others have attacked the Second Analogy for the famed non-sequitur by which Kant seems to assume without argument that nature adheres to the schematized concept of causality (Bennett 1966: 229; Strawson 1966: 137).

It may come as a surprise, then, to note that work on Kant's theory of science underwent something of a renaissance in the latter part of the twentieth century. The resurgence of interest was partly motivated by the pioneering work of Peter Plaass, Gerd Buchdahl, Robert Butts, Gordon Brittan and Philip Kitcher, who appealed to Kant's philosophy in response to a renewed emphasis on lawfulness in philosophy of science. Plaass ([1965] 1994) criticized the interpretation of Kant's critical philosophy that prevailed in the early twentieth century, which called on contemporary discoveries in mathematics and physics to expose Kant's supposedly outdated account of space and time as pure intuitions. Instead, he appealed to transcendental idealism to clarify the metaphysical foundations of contemporary physics, claiming that the

application of mathematics to the objects of scientific inquiry could never be grounded on a reality independent from thought but must depend on the structure of objecthood anticipated by the understanding. Buchdahl (1969) contended that the schematized categories of the understanding do not govern how natural objects behave, which would entail a problem of inference from general category to particular law. Rather, the schematized categories prescribe the logical relations of dependence between appearances and their conditions, enabling the natural scientist to seek real causal relations that possess a non-logical, nomic necessity.³ It is not the understanding but reason that ‘injects’ necessity into candidate lawlike propositions by virtue of the position they come to hold in a system of lawlike statements (Buchdahl 1969: 508–9). Generalizations ‘accrue’ necessity if they consistently and interdependently find their place in the best system.⁴ Buchdahl’s reading highlights the way in which reason produces guiding ideas, which, formulated as principles, instruct how candidate lawlike propositions should be judged. While the ideas of reason are not constitutive of laws, they provide epistemic justification for adopting a rule as a law.

As Plass and Buchdahl sought to reanimate Kant’s philosophy of science, the question of lawfulness became a central issue in the philosophy of science. For David Lewis (1973: 73), generalizations can be counted as natural laws if they are axioms in all the deductive systems with the best combination of simplicity and strength. Thus, there is nothing intrinsic about a certain property or power. Extrinsic matters fix the powers that bearers have. In contrast, David Armstrong (1983: 85) rejected the subjective character of the ideals that govern Lewisian systematization and argued instead that the laws of nature consist of non-logical or contingent necessitation relations between universals. According to Armstrong’s necessitarianism, lawfulness does not supervene on local matters of fact, nor does it depend on subjective requirements. It is a relation that holds between the universals in which the particular instances of those universals participate.

Both accounts have well-noted problems. Defenders of necessitarianism criticize the Lewisian view for conceding that laws, because they are grounded in subjective ideals (simplicity, strength and balance), are mind-dependent (Armstrong 1983: 66–73). Others claim that the Lewisian view raises a direction of fit problem. If a law supervenes on the occurrence of some fact, then it does not explain the occurrence of the fact. Rather, the occurrence of the fact explains the law; the direction of explanation goes the wrong way (van Fraassen 1989: 40–64). Critics of Armstrong’s necessitarian view argue that it raises a problem of inference (van Fraassen 1989: 96). Because laws are not causes, for they do not appear in space and time, the necessitarian view does not explain how they necessitate the empirical goings-on of nature (Lewis 1983: 366).

In the midst of this debate, several philosophers of science appealed to Kant to clarify some of the ambiguities associated with the notion of ‘best system’. Earlier in the century, Frank Ramsey ([1928] 1978) considered the best system as a fully deductive system of things we know. A system is ‘best’ if it is simpler than alternative systems. For Lewis (1986), the best system is a system of both particular and general truths, but not necessarily deductive. The best system thus has the pragmatically best trade-off between simplicity and informativeness. Yet neither the Ramseyan nor the Lewisian principles can be justified objectively. In response, Philip Kitcher attempted

to vindicate principles of systematicity by appealing to the indirect objective validity of reason's principles in the Transcendental Dialectic (CPR, A665/B693).⁵ Following Kant, Kitcher argues that the best system is the one that brings greatest unity and extension to the understanding, the latter of which is valid in regard to objects. Reason's principles coordinate the activities of the understanding and share in the objective validity of the categories to the extent that they (reason's principles) introduce empirical laws – non-trivial and non-logical propositions that fill in the cause-effect template anticipated by the schematized concept of causality – to the best system (Kitcher 1986: 209).

Kitcher's attempt to fuse Kant's account of lawfulness with the Lewisian best-system view has gained significant attention over the years. Yet few commentators have been convinced. As an interpretation of Kant, it fails to connect the necessity accrued by reason's systematicity with the necessity spontaneously determined by the understanding (Friedman 1992). As a revised Lewisian view, it fails to overcome the problem of fit, for systematic unity cannot explain how laws necessitate or govern spatio-temporal events in nature (Messina 2017: 136; Engelhard 2018: 30). Kant clearly states in the Dialectic that empirical inquiry merely 'approximates' the kind of universality that knowledge seeks (CPR, A647/B675). To address this problem, Michael Friedman (1992: 163) emphasized the necessitarian dimensions found in Kant's account of causation, claiming that laws, insofar as they 'subsume such regularities under the *a priori* principle of causality, . . . are necessary – and even, in a sense, *a priori*'. Friedman's account grants two classes of particular laws: the laws of mechanics, which are derived by applying the transcendental laws to the empirical concept of matter (MFNS, 4: 496; cf. P, §38), and mixed particular laws, which require content beyond the empirical concept of matter (MFNS, 4: 518; cf. CPR, A662–3/B690–1). Both classes of particular law are nomically necessary to the extent that the transcendental laws are 'injected' into them (Friedman 1992: 175), meaning that they govern how nature *must* behave.

Friedman's necessitarian account helped to establish that pure and mixed particular laws, if they are to govern material objects, must be grounded in the categories. Yet his necessitarian reading comes with the caveat that the remainder of particular laws, which are not grounded in the categories, are not strictly laws. While this conclusion appeals to some, for it paints Kant as an empiricist about particular domains of science while maintaining necessitation as an ideal, it opens a problem of inference similar to that raised by van Fraassen against Armstrong. The understanding's laws are not causes, for they do not appear in space and time and thus cannot act on spatio-temporal things (Engelhard 2018: 28). On Friedman's reading, there is no legitimate way to infer from the necessity of possible objects to the necessity of empirical goings-on (Massimi 2017: 150–1).

Given these problems, Kant scholars have found a new way of presenting the non-logical necessity of particular laws by engaging with the broader turn to causal powers (Watkins 2005; Kreines 2009; Stang 2016; Messina 2017) and dispositions (Massimi 2017; Engelhard 2018) in contemporary philosophy of science. These scholars argue that the relation between necessitation and systematicity need not be antagonistic. While Kant derives a small set of particular laws from the categories in *Metaphysical Foundations*, he does not say that lawfulness *requires* derivation from the

categories (Messina 2017: 138). James Kreines (2009: 528) defines a particular law as a proposition that identifies ‘a kind on whose nature some regularity depends, in the sense that it is necessitated by the nature of that kind’. Several ways of introducing the metaphysical idea can be found in the literature. Eric Watkins (2005: 244) argues that substances have natures that confer a certain causal power if certain conditions obtain. Nick Stang (2016: 229) draws from Kant’s lectures on metaphysics to frame a similar idea in terms of essences. Kristina Engelhard (2018: 8) defines the properties that are relevant for scientific explanations as dispositions. Each presentation shares the view that the lawfulness of particular laws is neither injected into empirical generalizations from above nor projected on them by virtue of the place they take in the best system of laws, but grounded from below. Particular laws can thus be described as categorially contingent and yet metaphysically (i.e. nomically) necessary (Stang 2016: 228).

The necessitarian account of lawfulness has clear strengths. In contrast to the best-system reading, it explains how laws govern natural processes. And in contrast to Friedman’s derivation reading, it explains how non-logical relations can be necessary: they are grounded in the properties of objects or relations between properties in nature. Yet several commentators have argued that if the necessity of particular laws is grounded metaphysically – in the real essence of things, which, for Kant, is inscrutable to us (see *L-Met/H*, 28: 553) – then particular laws are not epistemically available (Kreines 2009: 536; Messina 2017: 138). Critical philosophy rules out essences as the grounds for our knowledge claims. The problem here is that, once the metaphysical grounding of particular laws has been separated from the epistemic conditions of experience, metaphysics cannot be directly reconnected with experience without departing the secure land of truth for the stormy sea of illusion.

The conclusion of nomological ignorance opens several interpretive issues. Pragmatically, it undermines a potential exchange between Kant scholars and causal powers theorists. For causal powers theorists, powers simply are the expressed properties of substances and are fully available to our cognition (Mumford and Anjum 2011: 5). As a reconstruction of Kant’s position, it makes it difficult to see why we should seek particular laws in the first place. In this special issue, Lorenzo Spagnesi (Spagnesi 2023) argues that, if we cannot have knowledge of empirical laws, it is not clear why we should aspire to know them or how we would go about it even if we tried.

To address these issues, several scholars have pointed to numerous instances in Kant’s critical works where he clearly assumes that there are particular laws, and, moreover, that we are acquainted with them (*MFNS*, 4: 468; 4: 534; *CPR*, A766/B794; *P*, 4: 318; *CJ*, 20: 203–5; 5: 180–1). They propose alternative necessitarian readings – McNulty (2015) defends an ‘ideational’ interpretation of Kantian science, Engelhard (2018) a ‘broad’ interpretation and Breitenbach (2022) a ‘normative’ interpretation – each of which affords ‘knowledge’ (Engelhard 2018: 9) or ‘cognition’ (Massimi 2017: 169; Breitenbach 2018: 114) of particular laws.⁶ While Kant is clear that real essences are inscrutable to us, he nevertheless states that we cognize many of their essential aspects (*L-Met/H*, 28: 553). Reason’s ideas guide the understanding in search of the essential properties of empirical objects, such that we can discover the causally salient property by means of a hypothetic-deductive procedure (we come to know, for

instance, that sunlight melts wax; A766/B794). As Engelhard (2018: 31) puts it, to have a disposition means that a property is essentially linked with a specific causal profile, which confers a causal power. We ‘have full epistemic access to the powers’, she contends, ‘since we know what they do’ (Engelhard 2018: 9).

A brief overview of the scholarship on Kant’s account of natural laws indicates that broader debates in the philosophy of science have pushed Kant scholars to grapple with the complexity of his account. The necessitarian account of lawfulness opened space for new work on Kant and particular domains of science, for it demonstrates how empirical concepts and particular laws, which cannot be derived from the understanding’s relational categories, can nevertheless be treated as laws. The Lewisian best-system reading led Kant scholars to draw out the regulative use of reason Kant defends in *Critique of Pure Reason* and to unpack the connections between the transcendental principles that the understanding must ‘presuppose’ if it is to find unity in the manifold of cognitions. Of course, the impasse between the necessitarian and neo-Humean accounts of lawfulness has opened other new positions, including anti-realism (van Fraassen 1980) and the disunity of science (Cartwright 1999; Dupré 2001). Yet as Sabina Vaccarino Bremner (2023) demonstrates in this special issue, Kant provides an alternative that enables scholars to hold necessitation together with a system of laws that is always under revision. An exciting position that is currently developing simultaneously in philosophy of science and Kant studies emphasizes the role of the human standpoint in scientific inquiry (see Massimi 2022; Spagnesi 2022).

It should not surprise us that the shifts in Kant studies often track broader currents in philosophy of science. One might of course conclude that Kant scholarship is an isolated field that merely follows broader trends. We propose an alternative view, according to which the scholarship on Kant’s theory of natural science can be seen as part of a broader examination in philosophy of science of the justification we have for assuming lawfulness as a legitimate goal in the first place. Kant scholarship does not always lead to consensus. In fact, it regularly catalyses disagreements. Yet disagreements can nevertheless help us to clarify the assumptions we hold about lawfulness and to test whether we are able to justify them. In the following section we turn to another area of philosophy of science where Kant has periodically made an appearance, especially at moments of disagreement. Exploring how Kant has been utilized in philosophy of biology, we suggest, can help articulate the available positions and evaluate their costs and benefits.

3. Kant and biology

Anyone who has dipped into the literature on Kant and biology will know that it is full of controversies. In this section we show that these controversies track conceptual difficulties that philosophers of biology have also faced – and continue to face – since the *Critique of the Teleological Power of Judgement* was published in 1790. To do so, we explore the reasons why philosophers of biology continue to appeal to Kant and where these appeals align or deviate from his critical project. We are not interested in policing the acceptable moves one can make under the banner of transcendental philosophy. Focusing on what philosophers of biology are doing when they appeal to Kant, we suggest, can help us to mark out key problems arising in contemporary biological theory.

The controversies in the literature begin with Kant's relation to the emerging field of biology in the late eighteenth century. While he famously denied the possibility of a Newton who could explain the generation of a blade of grass (CJ, 5: 410), Kant described the problems specific to the investigation of living beings – especially in relation to the Newtonian framework – with uncharacteristic clarity.⁷ When he exchanged his work with Blumenbach in the 1780s, the two philosophers seemed to agree that Blumenbach's conception of the formative drive (*Bildungstrieb*) was compatible with Kant's critique of teleological judgement (CJ, 5: 424; Corr, 11: 185). Yet several scholars have since noted that their agreement was superficial, meaning that neither Kant nor Blumenbach interrogated the disparities between their respective projects.⁸ These disparities, we suggest, reflect an ambiguity in Kant's account of organic structure that, misunderstandings aside, has been productive for engagements between Kant scholars and philosophers of biology.⁹

The ambiguity we have in mind concerns the epistemic status of teleological judgements. Are organisms governed by an organizational force we come to know *through* experience, or does the appearance of organized beings merely display the form of judgement we bring *to* experience? To grasp how this ambiguity can be productive, consider the impact of Timothy Lenoir's (1982) account of Kant's role in the development of a biological science on philosophers of biology. Lenoir affirms the apparent similarity between Blumenbach and Kant and contends that Kant played an instrumental role in advancing the programme of comparative anatomy, which identifies similarities between organizational forces. Building on Lenoir's account, several philosophers of biology contend that Kant offers an alternative to the Neo-Darwinian attempt to replace purposiveness with the fitness value bestowed on random mutations by selection pressures. For instance, Lenny Moss and Stuart Newman (2015: 110–11) note that recent work in the biology of developmental systems raises a problem for Neo-Darwinism. Specifically, it fails to consider the activity of biological individuals, which stabilizes environmental states and thereby affects the selective pressures that act upon them. Moss and Newman propose a re-engagement with Kant's account of inner purposiveness to develop a new framework for biology capable of extending the range of causal relations at play in the evolutionary process. Now, there is no doubt that Kant's account of the organism emphasizes the inner purposiveness of living beings. Yet as John Zammito (2006, 2012) has argued at length, Lenoir's interpretation fails to acknowledge that teleological judgement for Kant enables us to reflect on certain natural objects *as if* they were purposive (CJ, 5: 397). For Blumenbach (1789: 25), the formative drive is analogous to Newton's gravitational force, such that purposiveness marks out an autonomous domain of living beings. While Kant and Blumenbach's apparent agreement has led several scholars to call on Kant for an extended account of biological causation, it simultaneously underplays Kant's claim that physical teleology is inseparable from our capacity to judge.

Zammito's work has assisted Kant scholars to recognize the problems associated with Lenoir's assessment of Kant's historical influence. Yet it conflates two questions that, we suggest, should be held separate. The first is whether Kant's critique of teleological judgement is amenable to Blumenbach's constitutive account of organizational forces. The answer, Zammito (2012: 124–7) contends, is that it is not. The second is whether Kant's critique of teleological judgement can speak to

contemporary issues in philosophy of biology. For Zammito, a negative answer to the first question entails a negative answer to the second. Contemporary philosophers of biology aspire to naturalism, Zammito (2006: 749) claims, and Kant's attempt to remove Blumenbach's formative drive from the domain of nature means that he 'simply *cannot* be refashioned into a naturalist'. Yet the fact that scholars have misunderstood Kant's relation to Blumenbach has not inhibited others from making Kant palatable to philosophers of biology. Consider Hannah Ginsborg's important interpretation, which highlights relevant features of Kant's account of teleological judgement for the use of function talk in biology. Ginsborg (2015: 251) claims that Kant can help us to maintain the use of teleological judgements without introducing non-natural causes. In what sense, for instance, do we judge a seven-legged horseshoe crab to be deficient? We do not imply that it is *morally* deficient: that it fails to adhere to a normative standard of what a horseshoe crab must be. There would be nothing irrational about a species of crab that had evolved to have seven legs, or nine for that matter. Rather, we are saying that it is *physically* deficient: that this individual deviates from the primitive normative conditions that hold generally for its species (Ginsborg 2015: 251). Given that a horseshoe crab *ought* to have eight legs, we ask: why does this specimen have only seven? That answer can be given in entirely mechanical-causal terms. Teleological judgements are indispensable for biology, on Ginsborg's interpretation of Kant, because they enable us to investigate why a part is or is not there *without* introducing non-natural forces.

Ginsborg's interpretation establishes an important connection between Kant's critical account of teleology and recent literature on biological function. Yet it underplays certain aspects of Kant's philosophy that may be unpalatable to philosophers of biology. For instance, in the *Methodology* of the third *Critique*, Kant argues that moral and physical teleology are connected by a practical belief that humans are ultimate ends of the world (*CJ*, 5: 431). Our biological and moral ends, he claims, are potentially united by our rational capacity to direct our actions in such a way that we act as if the overall purpose of the world is to manifest the conditions for realising our moral endeavours. In passages like these, Kant seems to be saying more about how physical and moral teleology corroborate one another, despite their differences, rather than how our judgement picks out scientifically interesting phenomena. Ina Goy (2020: 103) pursues this idea by stressing the role of God in Kant's critique of teleological judgement. In fact, Goy's argument highlights the connection between Kant's theological concerns and his denial that teleological judgements form a part of proper science (*MFNS*, 4: 468, *CJ*, 5: 400; see Berg 2014: 2). While Kant denies that we can have knowledge of God, teleological judgement, by presupposing design in nature, hints at a divine origin. This reason partly motivates Kant to deflate teleology to regulative judgement. When his systematic motivations are laid bare, Kant's critique of teleological judgement seems to be less relevant to contemporary philosophy of biology.

To defend the relevance of Kant's critique of teleological judgement for philosophy of biology, scholars generally adopt one of two interpretations. The first interpretation – call it *idealism* about teleology – emphasizes Kant's epistemic or pragmatic concerns, according to which teleological judgements do not disclose scientific features of the world. The second interpretation – call it *realism* about teleology – emphasizes Kant's clear assertion that teleological judgement is an

irreducible condition of biological research (e.g. *CJ*, 5: 376) and his more opaque claim that teleological judgements are necessitated by empirically given conditions (e.g. *CJ*, 5: 396).¹⁰ Tracing this distinction can help us to see that both philosophers of biology and Kant scholars span a spectrum of interpretations, depending on which aspect of Kant's critique of teleological judgement they emphasize.

Those who endorse an idealist interpretation tend to hold the view that scientific understanding is incompatible with teleological language. In the *Analytic*, Kant states that by judging a product of nature teleologically we represent it in a way that does not explain its possibility but elucidates the relation between the whole and its parts by comparing it with another kind of causality we know through our own technical capacity (*CJ*, 5: 374–5). At best we can explain why we must judge certain natural products according to ends (i.e. to make them intelligible *for us*), but this is distinct from an explanation of their generation. Teleology thus falls outside the remit of natural science, despite being indispensable for our ability to pick out and examine organized beings. Even Darwin's conception of natural selection, which explains the acquisition of adaptive traits mechanically, does not escape the presupposition that biological entities, as phenomena, have teleological qualities. For a scientific explanation of an organism to avoid projecting teleological qualities onto nature, it would have to explain a spontaneous, self-catalytic form of organization on the molecular level. As Alix Cohen (2020: 135) notes, this would potentially reduce biology to a branch of physics and eradicate the distinction between living and non-living beings.

Marjorie Grene and David Depew (2004) present an idealist interpretation of Kant in their episodic history of biology. On their account, Kant is the first philosopher of biology to identify our subjective need to employ 'heuristic' or 'regulative' ideas to investigate living beings. Grene and Depew argue that Kant's resolution to the antinomy of reflecting judgement removes biology from the realm of scientific explanation, for it separates the teleological and the mechanical perspectives at the level of finite rational beings. The upshot of the resolution is that we can pursue mechanistic thinking 'to penetrate as far as we can into the interior structure of organisms ... with little or no fear that we will end up as materialists' (Grene and Depew 2004: 116; cf. *CJ*, 5: 413). If we were to attempt a mechanical explanation of the possibility of living beings, we would 'los[e] our grasp on the entities we are talking about'. On Grene and Depew's interpretation, the difference between the two maxims of the antinomy is that, while mechanism is the principle of scientific explanation, teleology delineates the biological content of nature in a merely descriptive capacity (see *CJ*, 5: 412). As we will see shortly, there is a partial convergence with teleological realism here: both interpretations maintain that teleology cannot be reduced to mechanical explanation. Yet in contrast to realists, idealists claim that teleological judgements do not describe irreducible features of nature. Philippe Huneman (2014: 192) for instance argues that biological functions arise only when we adopt a teleological stance, that is, when we are aware that the entities governed by teleological laws are inherently contingent, enabling us to ask *why* certain features are present rather than others. On Huneman's reading, teleology is only applicable to certain elements of nature, whereas mechanistic explanations apply to the whole of nature.

Idealist interpretations are united by the idea that Kant's critique of teleological judgement removes the tension between judgements of purposiveness and scientific explanation. They generally regard Kant as adopting a unified reductive account of nature, which is incompatible with the notion that functions are real features of the natural world. This might resonate with more recent attempts to justify reductivism, such as E. O. Wilson's (1998) return to Whewell's consilience of inductions. Yet in contrast to contemporary reductive strategies, Kant does not argue that the totality of experience should be reduced to a single scientific explanation. Rather, his account suggests that some aspects of experience fall outside of the domain of scientific explanation. On an idealist interpretation, teleology explains our propensity to deploy purposiveness as a guide for reflection on some natural products at the cost of being able to know their causal origins. For several idealists, this entails that teleological judgement is *merely* heuristic. Andrea Gambarotto and August Nahas (2022: 52) for instance downplay Kant's claim that it is necessary to judge some things teleologically (CJ, 5: 370) and instead interpret teleological judgement as a heuristic guide employed by biologists when they have certain research questions in mind. Other idealists take Kant at his word. Angela Breitenbach (2009: 32) argues that teleological judgement is an 'inevitable' perspective on living beings, even though it 'introduces a focus that goes beyond any empirical investigation of nature'.

In the past few decades, several teleological realists have appealed to Kant as a precursor to their position (Weber and Varela 2002; Kauffman 2013; Moreno and Mossio 2015). To show how Kant's critique of teleological judgement can be relevant to contemporary biology, they argue that discoveries in physics – in particular, the second law of thermodynamics – have resolved the antinomy of reflecting judgement. For instance, Stuart Kauffman argues that what Kant termed 'natural ends' are in fact negentropic systems that emerge from entirely natural processes. Biological entities manifest their agency by actualizing functions and can be aptly described as 'Kantian self-recreating wholes' (Kauffman 2013: 5–7). What distinguishes biology from other sciences is that it is not possible to identify laws that will explain how the biosphere is going to develop. Biospheric development cannot be predicted in advance, for life dynamically adapts to niche environments. Kauffman thus finds no problem with Kant's claim that there cannot be a Newton for biology who could explain the emergence of a blade of grass. The reason that laws are not applicable for our biological understanding is that organisms (Kantian self-recreating wholes) co-create their environmental niches, which in turn introduce new selection pressures that alter the evolution of the biosphere (Kauffman 2013: 16). Of course, an idealist would respond by saying that negentropic systems still require our capacity for teleological judgement to identify them. Given that Kauffman is not strictly interested in teleological judging but in organisms themselves, Kant's *critique* of teleological judgement is pushed into the background along with the broader practical questions that motivate his project.

To ensure a productive dialogue between idealists and realists coming from both Kant studies and philosophy of biology, it is vital to pay careful attention to where interpretations of Kant deviate from his original critique of teleological judgement and the consequences of this deviation for Kant's overall project. Gambarotto and Nahas (2022: 54) rightly point out that realists must soften Kant's insistence that proper science is strictly a body of *a priori* knowledge and thus cannot be said to be

Kantian in a strict sense. Their observation is noteworthy for Kant scholars, as it is the realist interpretations that have received a warmer reception in philosophy of biology over the past decade. In the idealist camp, there is disagreement about whether teleological principles play a merely heuristic role or whether our ability to pick out biological individuals presupposes the principle of purposiveness. Scholars often fail to state whether the disagreement primarily concerns the correct interpretation of Kant's critique of teleological judgement or the scope of biological theory, leaving some of the most productive encounters between Kant scholarship and philosophy of biology underexplored. Controversies aside, at the very least Kant can help us identify a salient point of agreement between the two camps: idealists and realists both claim that the concept of the organism is indispensable to our investigation of biological individuals. Yet the role of biological individuals in the evolutionary process, and how to carve up nature into discrete biological entities, remains a matter of debate in philosophy of biology.

4. Kant and contemporary philosophy of science

Having noted that Kant's philosophy – even when misunderstood – can be productive for multiple projects in philosophy of biology, in this final section we consider several recent developments in philosophy of science that have potential synergies with Kant scholarship. First, Kant's philosophy can offer resources for philosophers who emphasize the importance of values in science. Helen Longino (1990) for instance argues that in science we need to find a common language for the description of experience which would allow us to formulate hypotheses that can be understood by others. Just as Kant understood objectivity as an achievement of the knowing subject, Longino argues that objectivity arises from scientific communities that adopt principles promoting intersubjective criticism. Granted, the mark of scientific objectivity as intersubjective consensus among scientists falls short of Kant's vision of proper science as a body of *a priori* rules (MFNS, 4: 468). Yet it stands in proximity to Kant's broader account of knowledge in the Doctrine of Method, according to which an objectively sufficient ground – such as the agreement of others – is one that we take to be sufficient for holding a proposition to be true (see Willaschek and Watkins 2020). An increasing number of philosophers of science reject the goal of discovering fundamental principles. For instance, pluralists argue that for most scientific developments the Newtonian conception of laws is the exception rather than the rule (Cartwright 1999: 24; Dupré 2001: 166). They contend that scientific evidence generally tends to oppose rather than confirm the existence of universal laws of nature.

Angela Breitenbach and Yoon Choi (2017) outline a theory of unified pluralism they describe as a distinctly (albeit distant) Kantian approach to pluralism in philosophy of science. They argue that the benefits of pluralism can only be identified when it is constrained under scientific unity understood as a 'regulative ideal' (Breitenbach and Choi 2017: 398). Unified pluralism does not presuppose that an underlying unity of science exists. Rather, it holds that the epistemic virtues of pluralist perspectives can only be realized if scientists adopt the values of collaboration and cooperation. These values encourage scientists to identify how their theories address related problems from different perspectives. Unified pluralism

offers an appealing alternative to the dichotomy between unified and pluralist accounts of science. Yet pluralists may resist Breitenbach and Choi's proposal, for it encourages us to strive towards the ideal of unified science irrespective of the empirical evidence generated to support this idea. On a scientific level, it is unclear what this striving might look like beyond following the recommendation to incorporate the principles of cooperation and collaboration into scientific practice in general. On a pragmatic level, it is unclear how we could know whether our most concentrated efforts at scientific research adopt a regulative ideal of scientific unity. Take the creation and roll-out of vaccines in response to the coronavirus pandemic. The response to the pandemic required unprecedented action across disciplines and organizations, from biochemists to governments. Moradian et al. (2020) argue that such collective, large-scale action demonstrates the benefits of interdisciplinary approaches similar to those described by unified pluralism, and reveals the need for greater integration both within the sciences and between organizations. Yet the benefits (or relevance) of an overarching commitment to the regulative unity of science for this approach are difficult to evidence. It is more likely that the collective response to the pandemic was targeted to the specific ways that the coronavirus impacted lives on the biological and social levels.

An alternative Kant-inspired view might emphasize the role of intersubjective communication in refining our knowledge and reducing prejudicial bias. For instance, Massimi's (2022) perspectival realism proposes that intersecting scientific perspectives guarantee reliable knowledge in line with the Kantian explanation of knowledge of modally robust phenomena without the need to presuppose an obtainable unity of science. Consider again the philosophy of biology, where there is a growing consensus that a single, all-embracing concept of the organism is not only impossible to achieve but also undesirable in practice (see Muszynski and Malaterre 2021). The prevailing emphasis on genetic mechanisms in twentieth-century biology reinforced the idea that organisms are genetically homogenous individuals. Yet the evidence suggests that genetic homogeneity accounts for a small aspect of life, and there are many more examples of functional integration of diverse genetic lineages through examples such as symbiosis and super-organisms (Pepper and Herron 2008). The different criteria that scientists adopt for demarcating organisms will provide differing conclusions about what is included in the domain of biology (Clarke 2010). Concerns about our ability to define organisms, or the role of organisms in biology more generally, reignite issues associated with idealist interpretations of Kant's critique of teleological judgement. In this special issue, Anna Wilks (2023) argues that the recent emphasis on functional integration over genetic homogeneity should be understood as a process wherein biologists are transforming their regulative judgements about part/whole relationships (or purposes) in nature. Wilks presents a case in which Kant can help us to explain how biologists must first conceive of biological individuals before they become scientific objects of examination.

The recent discussion of model organisms in biology might inadvertently corroborate Kant's critique of teleological judgement. Rachel Ankeny and Sabina Leonelli (2020: 7) claim that '[m]odel organisms serve as the basis for articulating processes that are thought to be common across all (or most) other types of organisms'. What is particularly interesting from a Kantian perspective is that model

organisms exist at the intersection of artefacts and natural samples. In one sense they are natural; model organisms could not be created in a lab and many aspects of them are not well understood by scientists. In another sense they are artificial, for they are prepared for experimental lab use, which requires selection of relevant traits by researchers. These traits are often preserved over significant time periods and across generations (Ankeny and Leonelli 2020: 19). To use Ian Hacking's (1983) account of scientific activities, model organisms manifest both intervention and representation: they are immensely useful for generating biological knowledge, for they are more easily manipulated in laboratories, and they represent many organisms. From a Kantian perspective, model organisms show that biological knowledge is often dependent on the inferences made by scientists about suitability. We do not passively read biological knowledge from the book of nature, as it were, for in many cases we must actively manipulate organisms for knowledge to be produced. The use of model organisms to generate biological knowledge opens new opportunities for Kant scholarship, for they reveal the importance of social and scientific activities in the formation of biological knowledge.

Growing support for the disunity of science presents new opportunities to explore aspects of Kant's philosophy in the context of these debates (Dupré 1993; Dupré and Nicholson 2018). For disunity theorists, the idea that science is converging toward a single unified explanation of reality not only lacks empirical support, but it also sets a precedent for science that is not reflective of the factors driving scientific development. Angela Potochnik (2017) argues that scientific laws do not express metaphysical truths but serve to isolate and idealize specific causal networks. The upshot of Potochnik's account is that, to understand the development of science, we need to consider the psychological, social, political and economic networks that have contributed to its development; networks that are unlikely to converge on a single unified explanation of all reality (cf. Potochnik 2017: 208). Potochnik's broader aim is to demonstrate the challenges for drawing metaphysical principles from science, given that it is inseparable from the various biological and social constraints of being human. Of course, Potochnik is no Kantian, and she opposes the conditions that Kant establishes for proper science. Nevertheless, Kant's critical philosophy can speak to philosophers who are critical towards scientific realism, for it defends a framework of inquiry that both aspires to unity and yet accepts that a unified science is unachievable. Perhaps we are now learning from philosophers of science that a unified science is not even desirable. In this special issue, Michela Massimi (2023) highlights Kant's underlying concern with the societal implications of natural science and its impact on how we understand cosmopolitan rights, which has been undertheorized in the literature. Massimi demonstrates that Kant's philosophy can serve as a guideline for philosophers of science who embrace a human-centred approach to science and must therefore account for normativity within scientific practice.

5. Conclusion

Kant's theory of science remains a matter of interest for Kant scholars and philosophers of science alike. While there have always been dissenting voices arguing

that Kant's critical philosophy is at odds with natural science, new developments in philosophy of science continue to trigger engagements with his work. Just as Hempel's deductive-nomological account of covering laws in the 1940s prompted Kuhn to respond with a historicized account of the development of scientific theories as 'paradigm shifts' in the 1960s, debates concerning the theory and practice of science led the way for new work on Kant's philosophy of science we examined in section 2. A renewed interest in Kant's critique of teleological judgement followed the emergence of philosophy of biology as a discipline, pioneered in the 1970s by scholars including David Hull, Michael Ruse and Ernst Mayr. Debates about Kant's philosophy of biology trace back to the same period (e.g. McFarland 1970), and, as we saw in section 3, Kant's notion of inner purposiveness has continued to gain the attention of contemporary philosophers of biology. The idealist and realist interpretations of teleological judgement agree that functions are irreducible for thinking about biological entities, yet whether functions are a subjective feature of inquiry or real features of nature continues to be a matter of debate.

In section 4 we suggested several possibilities for Kant scholars to engage with broader aspects of contemporary philosophy of science. Studies of the organism in biology has become so multifaceted that it seems unlikely that a single all-encompassing definition of the organism will be established, which can be seen to support the role of judgement in demarcating organisms from other kinds of entities. Moreover, we noted that some of our biological knowledge is derived from model organisms that require us to judge these entities as having a larger scope of representation with respect to target populations. At times, furthering our scientific knowledge requires that we manipulate nature in a way that blurs the boundary between organism and artefact. Despite the growing support for pluralism in philosophy of science, Kant's philosophy continues to offer new perspectives on live debates that inform Kant scholarship and philosophy of science alike. While we have not addressed the relevance of Kant's philosophy to developments in other scientific fields, such as chemistry and physics, we hope that this special issue, taken as a whole, will open new paths for Kant scholarship in a wider range of areas. Such areas include the normative foundation of cosmopolitan rights (Massimi 2023), the necessity of empirical laws (Spagnesi 2023), the role of *a priori* principles in scientific reasoning (Vaccarino Bremner 2023), mereology and biological individuality (Wilks 2023) and the possibility of a proper natural science of corporeal nature (McNulty 2023).

Acknowledgements. It was a pleasure to work with the contributors to this special issue. We hope that readers find their work to be as thought provoking and potentially field defining as we have. A special thanks to Michela Massimi, Lorenzo Spagnesi, Anna Wilks, Richard Aquila, Bennett McNulty and Jakub Techert for comments on an earlier version of our introductory article. We also thank our anonymous reviewers for their constructive feedback.

Notes

1 Carnap (2003: 289) argues that because the conventional and the empirical are the only components of knowledge, 'there is no synthetic *a priori*'.

2 See Cartwright (1999: 232). Despite the general shift away from lawfulness in philosophy of science, there has been a concerted effort to develop an account of science that resists the assumption of

physicalism and yet refuses to give up on unity. Sellars (1962) and McDowell (1994) for instance draw from Kant to reject a hard separation of the space of reason from the space of laws.

3 Johnson (1924: 4–5) defined nomic necessity as a dependence relation that holds for universals of law. In contrast to universals of fact, which take the form ‘all Xs are Ys’, universals of law take the form ‘if anything of some given kind were characterized as X, it would be characterized as Y’. The grammatical shift from universals of fact to universals of law extends the range of the law into the modal realm, which implies a shift from epistemology to metaphysics.

4 Buchdahl (1965: 204, 206): ‘the necessity of laws must itself be regarded as a pure function of the regulative employment of reason’; ‘the lawlikeness of laws must be made dependent on reason and not the understanding’.

5 References to *Critique of Pure Reason* follow the standard A/B pagination in Kant (1999a). All other references to Kant’s work follow the standard Akademie pagination (Kant 1900–). We use the following abbreviations and translations: MFNS = *Metaphysical Foundations of Natural Science*; P = *Prolegomena to Any Future Metaphysics*; CJ = *Critique of the Power of Judgement*; Corr = Correspondence; L-Met/H = Metaphysik Herder.

6 For an overview of the debate, see Cooper (2023).

7 For a study of modern biology in light of Kant’s denial, see Cornell (1986: 408).

8 For an account of their substantive points of disagreement, and thus their misunderstanding, see Richards (2000: 20).

9 For an account of how misunderstandings of Kant have been productive in philosophy of biology, see Jones (2023).

10 For an extended account of the idealist and realist positions, see Cooper (2018).

References

- Ankeny, R. and Leonelli, S. (2020) *Model Organisms*. Cambridge: Cambridge University Press.
- Armstrong, D. (1983) *What is a Law of Nature?* Cambridge: Cambridge University Press.
- Bennett, J. (1966) *Kant’s Analytic*. Cambridge: Cambridge University Press.
- Berg, H. van den (2014) *Kant on Proper Science: Biology in the Critical Philosophy and the Opus postumum*. Amsterdam: Springer Netherlands.
- Blumenbach, J. F. (1789) *Über den Bildungstrieb*, 2nd edition. Göttingen: Johann Dieterich.
- Brutenbach, A. (2009) ‘Teleology in Biology: A Kantian Perspective’. *Kant Yearbook*, 1(1), 31–56.
- (2018) ‘Laws and Ideal Unity’. In W. Ott and L. Patton (eds), *Laws of Nature* (Oxford: Oxford University Press), 108–22.
- (2022) ‘Kant’s Normative Conception of Science’. In M. B. McNulty (ed.), *Cambridge Guide to the Metaphysical Foundations of Natural Science* (Cambridge: Cambridge University Press), 36–54.
- Breitenbach, A. and Choi, Y. (2017) ‘Pluralism and the Unity of Science’. *The Monist*, 100(3), 391–405.
- Brittan, G. (1978) *Kant’s Theory of Science*. Princeton: Princeton University Press.
- Buchdahl, G. (1965) ‘Causality, Causal Law, and Scientific Theory in the Philosophy of Kant’. *British Journal for the Philosophy of Science*, 16, 187–208.
- (1969) *Metaphysics and the Philosophy of Science*. Oxford: Blackwell.
- Butts, R. (1986) ‘The Methodological Structure of Kant’s Metaphysics of Science’. In R. Butts (ed.), *Kant’s Philosophy of Physical Science* (Dordrecht: D. Reidel Publishing Co.), 163–99.
- Carnap, R. (2003) *The Logical Structure of the World and Pseudoproblems in Philosophy*. Chicago: Open Court.
- Cartwright, N. (1999) *The Dappled World: A Study of the Boundaries of Science*. Cambridge: Cambridge University Press.
- Clarke, E. (2010) ‘The Problem of Biological Individuality’. *Biological Theory*, 5(4), 312–25.
- Cohen, A. (2020) ‘Kant on Evolution: A Re-evaluation’. In J. Callanan and L. Allais (eds), *Kant and Animals* (Oxford: Oxford University Press), 123–35.
- Cooper, A. (2018) ‘Two Directions for Teleology: Naturalism and Idealism’. *Synthese*, 195, 3097–3119.
- (2023) ‘Hypotheses in Kant’s Philosophy of Science’. *Studies in History and Philosophy of Science*, 99, 97–105.
- Cornell, J. (1986) ‘Newton of the Grassblade? Darwin and the Problem of Organic Teleology’. *Isis*, 77, 405–421.

- Dupré, J. (1993) *The Disorder of Things: Metaphysical Foundations of the Disunity of Science*. Cambridge, MA: Harvard University Press.
- (2001) *Human Nature and the Limits of Science*. Oxford: Oxford University Press.
- Dupré, J. and Nicholson, D. (2018) 'A Manifesto for a Processual Philosophy of Biology'. In D. Nicholson and J. Dupré (eds), *Everything Flows: Towards a Processual Philosophy of Biology* (Oxford: Oxford University Press), 3–45.
- Engelhard, K. (2018) 'The Problem of Grounding Natural Modality in Kant's Account of Empirical Laws of Nature'. *Studies in History and Philosophy of Science*, 71, 24–34.
- Friedman, M. (1992) *Kant and the Exact Sciences*. Cambridge, MA: Harvard University Press.
- (2013) *Kant and the Construction of Nature*. Cambridge: Cambridge University Press.
- Gambarotto, A. and Nahas, A. (2022) 'Teleology and the Organism: Kant's Controversial Legacy for Contemporary Biology'. *Studies in History and Philosophy of Science*, 93, 47–56.
- Ginsborg, H. (2015) *The Normativity of Nature: Essays on Kant's Critique of Judgement*. Oxford: Oxford University Press.
- Goy, I. (2020) 'Kant on Nonhuman Animals and God'. In J. Callanan and L. Allais (eds), *Kant and Animals* (Oxford: Oxford University Press), 89–104.
- Goy, I. and Watkins, E. (eds) (2014) *Kant's Theory of Biology*. Berlin: De Gruyter.
- Grene, M. and Depew, D. (2004) *The Philosophy of Biology: An Episodic History. The Evolution of Modern Philosophy*. Cambridge: Cambridge University Press.
- Hacking, I. (1983) *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science*. Cambridge: Cambridge University Press.
- Heidegger, M. (1967) *What is a Thing?* Trans. W. B. Barton and Vera Deutsch. Chicago: Regnery.
- Huneman, P. (ed.) (2007) *Understanding Purpose: Kant and the Philosophy of Biology*. Rochester, NY: University of Rochester Press.
- (2014) 'Purposiveness, Necessity, and Contingency'. In Ina Goy and Eric Watkins (eds), *Kant's Theory of Biology* (Berlin: De Gruyter), 185–202.
- Johnson, W. E. (1924) *Logic*. Vol. 3. Cambridge: Cambridge University Press.
- Jones, A. (2023) *How Kant's Philosophy Matters for Biology: A Philosophical History*. Cardiff: University of Wales Press.
- Kant, I. (1900–) *Kants gesammelte Schriften*. Ed. Königlich-Preußlichen Akademie der Wissenschaften (and successors). Berlin: Walter de Gruyter.
- (1999a) *Critique of Pure Reason*. Trans. and ed. P. Guyer and A. Wood. Cambridge: Cambridge University Press.
- (1999b) *Correspondence*. Trans. and ed. A. Zweig. Cambridge: Cambridge University Press.
- (2000) *Critique of the Power of Judgment*. Trans. P. Guyer and E. Matthews. Cambridge: Cambridge University Press.
- (2004a) *Prolegomena to Any Future Metaphysics*. Trans. and ed. G. Hatfield. Cambridge: Cambridge University Press.
- (2004b) *Metaphysical Foundations of Natural Science*. Trans. and ed. M. Friedman. Cambridge: Cambridge University Press.
- (1968/1970) *Metaphysik Herder, 1762–1764*, in *Vorlesungen über Metaphysik*, vols. 28.1 and 28.1.1 of *Kants gesammelte Schriften*. Ed. Gerhard Lehmann (Berlin: Walter de Gruyter), 1–524, 525–987.
- Kauffman, S. (2013) 'Evolution Beyond Newton, Darwin, and Entailing Law'. In B. Henning and A. Scarfe (eds), *Beyond Mechanism: Putting Life Back into Biology* (Plymouth: Lexington Books), 1–24.
- Kitcher, P. (1986) 'Projecting the Order of Nature'. In R. Butts (ed.), *Kant's Philosophy of Physical Science* (Dordrecht: D. Reidel Publishing Co.), 201–38.
- Kreines, J. (2009) 'Kant on the Laws of Nature: Laws, Necessitation, and the Limitation of our Knowledge'. *European Journal of Philosophy*, 17(4), 527–58.
- Lenoir, T. (1982) *The Strategy of Life: Teleology and Mechanics in Nineteenth-Century Biology*. Dordrecht: D. Reidel.
- Lewis, D. (1973) *Counterfactuals*. Cambridge, MA: Harvard University Press.
- (1983) 'New Work for a Theory of Universals'. *Australasian Journal of Philosophy*, 61, 343–77.
- (1986) *On the Plurality of Worlds*. Oxford: Basil Blackwell.
- Longino, H. (1990) *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry*. Princeton: Princeton University Press.

- Massimi, M. (2017) 'Grounds, Modality, and Nomic Necessity in the Critical Kant'. In M. Massimi and A. Breitenbach, *Kant and the Laws of Nature* (Cambridge: Cambridge University Press), 150–70.
- (2022) *Perspectival Realism*. Oxford: Oxford University Press.
- (2023) 'Normative Foundations of Kant's Cosmopolitan Right: The Overlooked Legacy of Kant's Metaphysics of Nature'. *Kantian Review*. doi: [10.1017/S1369415423000158](https://doi.org/10.1017/S1369415423000158).
- Massimi, M. and Breitenbach, A. (eds) (2017) *Kant and the Laws of Nature*. Cambridge: Cambridge University Press.
- McDowell, J. (1994) *Mind and World*. Cambridge, MA: Harvard University Press.
- McFarland, J. (1970) *Kant's Concept of Teleology*. Edinburgh: Edinburgh University Press.
- McNulty, M. B. (2015) 'Rehabilitating the Regulative Use of Reason: Kant on Empirical and Chemical Laws'. *Studies in History and Philosophy of Science*, 54, 1–10.
- (2023) 'What Mathematics and Metaphysics of Corporeal Nature Offer to Each Other: Kant on the Foundations of Natural Science'. *Kantian Review*. doi: [10.1017/S1369415423000250](https://doi.org/10.1017/S1369415423000250).
- Messina, J. (2017) 'Kant's Necessitation Account of Laws and the Nature of Natures'. In M. Massimi and A. Breitenbach (eds), *Kant and the Laws of Nature* (Cambridge: Cambridge University Press), 131–49.
- Moradian, N. et al. (2020) 'The Urgent Need for Integrated Science to Fight COVID-19 Pandemic and Beyond'. *Journal of Translational Medicine*, 18, 205.
- Moreno, A. and Mossio, M. (2015) *Biological Autonomy: A Philosophical and Theoretical Enquiry, History, Philosophy and Theory of the Life Sciences*. Dordrecht: Springer Netherlands.
- Moss, L. and Newman, S. (2015) 'The Grassblade beyond Newton: The Pragmatizing of Kant for Evolutionary-Developmental Biology'. *Lebenswelt*, 7, 94–111.
- Mumford, S. and Anjum, R. (2011) *Getting Causes From Powers*. Oxford: Oxford University Press.
- Muszynski, E. and Malaterre, C. (2021) 'A Roadmap to Explanatory Pluralism: Introduction to the Topical Collection The Biology of Behaviour'. *Synthese*, 199, 1777–89.
- Pepper, J. W. and Herron, M. D. (2008) 'Does Biology Need an Organism Concept?'. *Biological Reviews*, 83(4), 621–7.
- Plass, P. (1994) *Kant's Theory of Natural Science*. Trans. and ed. Alfred E. and Maria G. Miller. Dordrecht: Springer.
- Potochnik, A. (2017) *Idealization and the Aims of Science*. Chicago: University of Chicago Press.
- Ramsey, F. (1978) 'Universals of Law and of Fact' [1928]. In D. H. Mellor (ed.), *Foundations: Essays in Philosophy, Logic, Mathematics and Economics* (Atlantic Highlands, NJ: Humanities Press), 128–33.
- Richards, R. (2000) 'Kant and Blumenbach on the *Bildungstrieb*: A Historical Misunderstanding'. *Studies in History and Philosophy of Biology and Biomedical Sciences*, 31, 11–32.
- Sellars, W. (1962) 'Philosophy and the Scientific Image of Man'. In R. Colodny (ed.), *Science, Perception, and Reality* (New York: Humanities Press/Ridgeview), 35–78.
- Spagnesi, L. (2022) 'Kant's Space of Theoretical Reason and Science: A Perspectival Reading'. In L. Caranti and A. Pinzani (eds), *Kant and the Problem of Knowledge* (London: Routledge), 109–35.
- (2023) 'The Necessity of Empirical Laws of Nature through the Lens of Kant's Dialectic'. *Kantian Review*. doi: [10.1017/S1369415423000274](https://doi.org/10.1017/S1369415423000274).
- Stang, N. (2016) *Kant's Modal Metaphysics*. Oxford: Oxford University Press.
- Strawson, P. (1966) *The Bounds of Sense*. London: Methuen.
- Vaccarino Bremner, S. (2023) 'Relativizing the A Priori Through Reflective Judgement'. *Kantian Review*. doi: [10.1017/S1369415423000262](https://doi.org/10.1017/S1369415423000262).
- van Fraassen, B. (1980) *The Scientific Image*. Oxford: Oxford University Press.
- (1989) *Laws and Symmetry*. Oxford: Clarendon.
- Watkins, E. (ed.) (2001) *Kant and the Sciences*. Oxford: Oxford University Press.
- (2005) *Kant and the Metaphysics of Causality*. Cambridge: Cambridge University Press.
- (2019) *Kant on Laws*. Cambridge: Cambridge University Press.
- Weber, A. and Varela, F. (2002) 'Life After Kant: Natural Purposes and the Autopoietic Foundations of Biological Individuality'. *Phenomenology and the Cognitive Sciences*, 1(2), 97–125
- Wilks, A. F. (2023) 'The "Whole" Truth about Biological Individuality in Kant's Account of Living Nature'. *Kantian Review*. doi: [10.1017/S1369415423000249](https://doi.org/10.1017/S1369415423000249).
- Willaschek, M. and Watkins, E. (2020) 'Kant on Cognition and Knowledge'. *Synthese*, 197, 3195–3213.

Wilson, E. O. (1998) *Consilience: The Unity of Knowledge*. New York: Vintage Books.

Zammito, J. (2006) 'Teleology Then and Now: The Question of Kant's Relevance for Contemporary Controversies over Function in Biology'. *Studies in History and Philosophy of Biology and Biomedical Sciences*, 37(4), 748–70.

—— (2012) 'The Lenoir Thesis Revisited: Blumenbach and Kant'. *Studies in History and Philosophy of Biology and Biomedical Sciences*, 43(1), 120–32.