Realism and the Limits of Explanatory Reasoning

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1. Introduction

The nature and limits of scientific explanations and explanatory reasoning are central topics in philosophy of science. They are also important in the scientific realism debate, where much has been written about *inference to the best explanation.* In this chapter I will first examine issues surrounding inference to the best explanation, its justification, and its role in different realism arguments, before turning to more general issues concerning explanations' ontological commitments.

Throughout the chapter I stress the importance of thinking carefully about the nature of explanation in connection with addressing issues related to explanatory reasoning and scientific realism. Undoubtedly this is easier said than done: the nature of scientific explanation is a broad and controversial topic in its own right. A decade-and-a-half ago Newton-Smith (2000) rightly complained that philosophical analyses of scientific explanation is 'an embarrassment for the philosophy of science' – a 'scandal' comparable to what Kant thought scepticism was to epistemology:

> While we have insightful studies of explanation, we are a very long way from having this single unifying theory of explanation. […] [W]e would like to be able to explain what it is that leads us to count different explanations as explanatory. This task is made all the more pressing as most philosophers of science hold that *a* main task, if not *the* main task, of science is to provide explanation, whatever that may be. (p. 132)

Although studies of explanation have progressed in leaps and bounds since the turn of the millennium, we are still far from having reached a broad consensus, and explanation-centred debates within the realism debate continue to suffer from lack of contact with the best work done in the philosophy of explanation.

The challenges in pinning down a theory of explanation hardly reduces its significance, however. Indeed, it is easy to appreciate the importance of having a good grasp on *what it is to explain*, prior to trying to determine the nature and limits of inference to the *best* explanation. As Newton-Smith (ibid.) forcefully points out:

> [I]t is hard to see how we will be able to adjudicate the substantial claims about the relation of explanation to epistemology without such a unifying account. Realists, for instance, typically claim that the greater a theory's explanatory power, the greater its likely truth or approximate truth. Without the backing of a unifying account of explanation, this claim is suspect. (p. 132)

It is an open question, of course, whether any such *unifying* account of explanation can be given, or whether some sort of pluralism is in the offing (cf. Reutlinger and Saatsi 2017: §1). Either way, it is critical to emphasise the importance to the realism debate of a decent grasp of the nature of explanation. In this chapter I will discuss different issues to this effect, first in connection with the realists' appeal to inference to the best explanation (Section 3), and then with respect to more general questions concerning explanatory indispensability and ontological commitment (Section 4). In both contexts I aim to bring out how recent

developments in the philosophy of explanation fruitfully intersect with the scientific realism debate. But before we get to these matters I need to provide some context (Section 2).

2. Some context

Explanations and explanatory reasoning are at the heart of the sciences, which in large part seem to be in the business of helping us understand the world. For instance, the standard model of particle physics appeals to the Higgs boson and spontaneous symmetry breaking in order to explain why some particles have mass. For a much less theoretical and less contemporary example, consider Darwin's theory of natural selection, which beautifully explains the evolution of replicating living things. Perhaps the perceived explanatory goodness of these theories is (at in partly) responsible for their high standing? Consider Darwin's comment in *The Origin of Species* on the wealth of evidence, including morphological and embryological data, supporting natural selection:

> [I]t can hardly be supposed that a false theory would explain, in so satisfactory a manner as does the theory of natural selection, the several large classes of facts above specified. It has recently been objected that this is an unsafe method of arguing; but it is a method used in judging of the common events of life, and has often been used by the greatest natural philosophers (Darwin, 1962, p. 476).

Amongst the greatest natural philosophers one finds Newton (1687), whose first methodological rule in *Principia* states: "No more causes of things should be admitted than are both true and sufficient to explain their phenomena." Whewell (1858) takes the quest for the best explanation to be at the heart of Newton's method. He summarises his own idea of 'consilience of inductions' thus:

> [T]he evidence in favour of our induction is of a much higher and more forcible character when it enables us to explain and determine cases of a kind different from those which were contemplated in the formation of our hypothesis. The instances in which this has occurred, indeed, impress us with a conviction that the truth of our hypothesis is certain. No action could give rise to such an extraordinary coincidence. (pp. 87–8)

These are famous examples of arguably commonplace methodological references to explanation in science, supporting the idea that theories' perceived capacity to explain phenomena is often much more than an output of successful science: it is also an *input for scientists' assessment of the evidential support for theories*. The exact role of explanatory considerations in the scientific methodology is a contested topic, but one prominent school of thought views scientists' evaluations of explanatory goodness as the very guide to making many ampliative (i.e. deductively invalid) inferences in science (e.g. Boyd 1981, Lipton 2004, Psillos 1999, McCain 2016). According to this tradition scientific inferences are (often) made to the best available explanation – that is, they are inferences to the best explanations.[1]

There are substantial questions about the notion of inference to the best explanation (IBE) – to be sharpened shortly (§3) – as a characterization of the scientific method, confirmation, and theory-choice. In confirmation theory the dominating Bayesian trend is probabilistic, and the relationship between Bayesianism and explanatory reasoning is a contested topic of significant current interest (see Douven 2017: §4). Independently of that specific issue, many contemporary philosophers put much less weight on explanatory reasoning in interpreting the

[1] See Lipton (2004) for a classic exposition and defence of this line of thought, and Douven (2017) for a nice review.

methodological pronouncements of Newton or Darwin, or in making sense of theory-choice in contemporary physics, for example (e.g. Achinstein 2013, Dawid 2013). Some very prominent figures in the philosophy of science from Mach and Duhem onwards have downplayed the explanatory dimension of science. According to the latter, for example, "a physical theory […] is an abstract system whose aim is to summarise and classify logically a group of experimental laws without claiming to explain these laws" (Duhem 1906, p. 7). Some of the most influential contemporary anti-realists belong to this tradition that downplays the epistemic importance of explanation. Neo-instrumentalists, such as Stanford (2006), regard fundamental scientific theories as effective instruments for prediction, manipulation and control of phenomena, not as explanatory descriptions of the reality beyond those phenomena. Similarly, empiricists to this day regard as suspect scientific explanations of observable phenomena in terms of unobservable causes and laws, and in as far as scientists themselves put weight on the explanatory virtues of theories, empiricists, such as van Fraassen (1980, 2004), tend to regard these virtues as merely pragmatic, as opposed to epistemic. (Even if it is the case that according to the scientific standards theories that explain better, really *are* better – generally speaking, other things being equal – it does not automatically follow that explanatory judgements are truth-conducive, or that explanatory understanding should be the aim of science.)

Realists, by contrast, tend to put much more weight on the explanatory dimension of science, noting that the core explanatory ingredients in science routinely make indispensable reference to unobservable causes, mechanisms, symmetries, laws, and so on, all of which naturally involve epistemological and ontological commitments that anti-realists denounce. Hence, standing for the explanatory aspirations of science and its aim to give us *genuine understanding* of the world behind the appearances arguably requires a realist commitment to whatever is doing the explaining. Empiricists' desire to make sense of science without 'inflationary metaphysics' of laws of nature, natural kinds, and objective modality motivates a distinctly pragmatic account of explanation, according to which a theory's explanatory goodness is just a matter of the theory providing answers to context-sensitive why-questions, which is something that false theories can also do perfectly well (van Fraassen 1980). The tenability of such deeply pragmatic account of explanation is highly questionable, however (e.g. Kitcher and Salmon 1987).

How much metaphysics does a realist have to embrace to capture the alleged explanatory success of science? This question is at the heart of some of the current controversies regarding scientific realism.[2] Answering it requires engaging with philosophical accounts of causation, natural kinds, and explanation. For whether or not genuine explanatory success requires correctly representing non-Humean causal connections, say, depends on *what it is to explain*. While some have defended more metaphysically-laden views of scientific explanation (e.g. Salmon 1984, Craver 2007), others have attempted to stay much more neutral on the metaphysics of causation and explanation (e.g. Woodward 2003). If a metaphysically 'thin' modal account of explanation is defensible, it may also offer a way to capture the explanatory successes of metaphysically more troublesome areas of science, such as quantum physics, where the realist might want to avoid making any specific metaphysical commitments.[3]

[2] See Steven French's 'Realism and metaphysics' and Matthew Slater's 'Natural kinds' (this volume) for further discussion.

[3] Indeed, some have argued that one need not be a realist at all in order to capture the explanatory achievements of quantum physics in modal terms. See Healey (2015).

Many realists have operated with ontologically more committing accounts of explanation in mind. A natural realist intuition is that 'to explain' is a success term: an *actual* explanation requires the (approximate) *truth* of the explanatory assumptions; else we merely have a *potential* explanation at best.[4] As a natural consequence many realists have regarded *explanatory indispensability* as the key to determining what is real. This tradition goes back to Quine and Sellars, and it has been recently championed by e.g. Baker (2009), Colyvan (2013), Field (1989), and Psillos (2005, 2011b). According to this line of thought our best scientific explanations and their ontological requirements fix the realist commitments. This raises questions about the status of mathematics, and abstract and idealised models, which can arguably play an indispensable explanatory role in accounting for empirical phenomena. The advocates of the explanatory indispensability argument have argued that we should extend our realist commitments from typical unobservable realist posits, like electrons, to mathematical and other *abstracta*. This holistic application of explanatory reasoning in defence of realism has become another point of contention in the scientific realism debate.

So much for general context setting. We have seen how issues concerning scientific realism, explanation, and IBE naturally arise from a positive epistemic attitude towards scientific explanations. The rest of this chapter presupposes that IBE can provide a valid description of at least some significant inferences in science. The philosophical issues to be discussed focus on the question of *justification*: what can we justifiably believe, or ontologically commit ourselves to, given such explanatory practices? Next I will discuss how some of the key *arguments for* realism, more specifically, turn on explanatory reasoning and IBE.

3. IBE and realist arguments

Let's now examine IBE and its connection to scientific realism in a bit more detail. As already said, the basic gloss on IBE is that explanatory considerations play an evidential role in science: the explanatory goodness of theoretical hypotheses is an important factor in the assessment and justification of those hypotheses. Putting a normative spin on it, we can say that according to IBE, explanatory virtues *should* be taken into account in assessing competing hypotheses' comparative likelihoods. To borrow Peter Lipton's (2004) turn of phrase: explanatory *loveliness* should be taken a guide to *likeliness*. It is natural to add some further constraints on this basic idea. In particular, we can demand that the competing hypotheses should be *good enough* (qua explanations) to be worth of inferring to, and we can further demand that the best explanation should be sufficiently clearly the best to be a worthy winner (cf. Lipton 2014, Douven 2017).

If realists could argue that this normative, justificatory idea of IBE is well grounded, we would have a good reason to epistemically prefer the theories and hypotheses arrived at by this method. This would not yet quite deliver the realist conclusion, however, since IBE (thus construed) does not yet say anything about *how likely* the best explanations are to be (approximately) true – the reliability of using explanatory loveliness as a guide to inductive likeliness is compatible with the possibility that our best explanations are not very likely to be (approximately) true. And why should we regard this idea of IBE well-grounded in the first place?

[4] This idea goes back to the truth-condition of Hempel's DN-model of explanation. See e.g. Hempel (1962).

This is where arguments for realism come in. Consider, for example, the standard No-Miracles Argument (NMA), which capitalises on the intuition that only scientific realism can account for the impressive empirical success of science. Exactly how 'empirical success' should be understood, and how it can be leveraged into an argument for realism, raise various issues that I am going to gloss over here.[5] The classic presentation of NMA, going back to Putnam (1978), simply puts the argument forward as an IBE: (i) the phenomenon to be explained is the empirical success of science; (ii) the realist idea that the best scientific theories and hypotheses are systematically latching onto reality gives the best explanation of that phenomenon; therefore (iii) realism is justified via the application of IBE.

A number of authors have attempted to further articulate and defend this kind of IBE-based argument for realism (e.g. Boyd 1981; Musgrave 1988; Barnes 2002; Psillos 1999: §4, 2009: §3, 2011d). Indeed, there are a number of fairly obvious, and well-known worries about NMA thus presented. Is the realist explanation really the best? Is it good enough? Doesn't the realist's application of IBE in her argument simply beg the question against those who are sceptical about IBE to begin with? There are equally well-known attempts to respond to these worries, detailed in, e.g., Psillos (1999, 2011d). It is worth noting that some of these responses substantially hinge on broader issues in epistemology, e.g. in relation internalism vs. externalism regarding justification, and how knowledge is analysed. In particular, arguably from an externalist perspective the realist's use of IBE in NMA need not beg the question against the IBE-sceptic, if our explanatory reasoning about the world (including science and its success) is *de facto* reliable.[6]

Let's dig a bit deeper into a couple of interesting features of NMA. Many advocates of NMA from Putnam onwards have presented it as a *methodologically naturalistic* argument that is continuous with scientific reasoning itself (Boyd 1981, Psillos 1999). That is, although the realist explanation takes as its data particular facts *about science* – namely, science's empirical success, as well as the role of explanatory reasoning as a driver of this success – the argument itself is meant to exemplify the very qualities that good scientific reasoning exhibits. There is clearly an air of circularity in the way the realists aim to justify scientific IBEs as well-grounded with this (meta-level) IBE about science, but realists have argued that this circularity is not pernicious. Instead of being viciously *premise*-circular, NMA involves a kind of *rule*-circularity, in that the rule of inference employed – namely, IBE – also appears in the conclusion of the inference (Psillos 1999). Arguably rule-circularity need not be problematic, at least from the point of view of externalist epistemology. It may be the case that the argument only succeeds in 'preaching to the converted' – namely those willing to adopt a realist *stance* at the outset. But that need not be a futile upshot, and perhaps it is the best we can hope for (Psillos 2011a).

An appropriate similarity between scientists' IBEs and the realist's meta-level IBE is critical for prominent vindications of NMA, but the status of NMA as a 'methodologically naturalistic' argument is far from straightforward. For example, Frost-Arnold (2010) argues that the realist explanation of the empirical success of science fails to satisfy the *scientific* criteria for a good explanation, because it is neither unifying, nor generates new predictions. Since NMA arguably fails to satisfy the scientifically-proven canons of a good explanatory inference, Frost-Arnold argues that it is not sanctioned by the tenets of naturalistic philosophy. If you take your cue for assessing explanatory goodness from the sciences, the

[5] See Brad Wray's 'Success of science as a motivation for realism' (this volume) for discussion.
[6] See Alexander Bird's 'Scientific realism and epistemology' (this volume) for further discussion.

realist explanation of the empirical success of science arguably does not come out as a good (enough) explanation to be warranted by IBE.

In my view Frost-Arnold's criticism of NMA presupposes too strict a conception of naturalism. It should be allowed that the realist explanation can be science-transcending and purely philosophical, in the sense that it does not enjoy the degree of *evidence* there is for paradigmatically good scientific explanations. The mode of inference can nevertheless be the same in the realist argument and in various scientific instances of theory-choice, even when the overall evidence (or epistemological standard) is not. As far as I can see, there is nothing in the tenets of methodologically naturalistic philosophy that commits the realist to the claim that her philosophical theory (about science) is supported to the same degree that scientific theories themselves are supported. One should not object to explanationism in the context of philosophy of science merely on the grounds that it does not have probative force on a par with the explanatory inferences in science (Saatsi 2016). After all, presumably there are reasons why the realist doctrine counts as a *philosophical* theory, as opposed to being scientific.

There are other, related aspects of NMA that one perhaps should find genuinely problematic, however. Consider, for instance, the rather *global* character of NMA. This single realist argument covers a lot of science in one fell swoop: all of (mature?) science that employs IBE-driven inferences and produces empirical successes of the requisite sorts. It is notable that many of these sciences have radically different kinds of subject matters – e.g. cosmology, quantum physics, molecular biology, geology, ecology – some of which are further removed from human everyday experience than others. (The other-worldliness of modern physics is a case in point, of course.) Arguably the modes of explanation employed also differ widely, some explanations being non-causal and abstract, while others are straightforwardly causal-mechanical, say. In the light of all this it is natural to worry that scientists' reliability in their explanatory reasoning could well vary a great deal from one domain of science to another. Perhaps we are, for instance, much less good at conceiving of all the alternative explanations in fundamental physics, than we are in molecular biology. And perhaps we are less reliable assessors of explanatory goodness in connection with quantum phenomena, than we are in connection with geology. On such grounds one might well worry that NMA over-generalises in its attempt to argue for realism about 'all of mature science' via a single application of IBE. The best explanation for empirical success could well differ from one area of science to another (Saatsi 2015).

Moreover, the (global) realist's inclination to generalise and abstract away from details of different subject matters goes further than this. In particular, when the realist emphasises the rule-circular character of NMA, she regards this particular philosophical IBE as being on a par, in a justificatory sense, with the scientific IBEs that are part of the subject matter of NMA (cf. Psillos 1999: §4). A philosophical (meta-level) IBE – namely NMA – that is about scientific IBEs, is meant to be a good inference by virtue of being the *same kind* of inference as the scientific IBEs. This kind of similarity between NMA and scientific IBEs can be claimed at a descriptive level by abstracting away from all the differences in the respective explanations that are at stake in the realist argument, on the one hand, and the various scientific inferences, on the other. (What is the nature of the realist explanation, exactly? It's not clear that any of the prominent accounts of scientific explanation apply to it.) But why think that those differences do not matter for our reliability in explanatory reasoning? To the contrary, given how different the realist explanation of the success of science is from all scientific explanations, we might well want to be sceptical of the realist's IBE, even if (many

of) the scientific IBEs are reliable inferences. The same point applies to various other philosophical IBEs, which are often justified by reference to empirically fruitful employment of IBE in science. (See Saatsi 2016 for more detailed discussion.)

The various issues with NMA speak against global explanationist realism. But there are other, less global arguments for realism, some of which turn on more piecemeal attempts to justify scientists' IBEs. For example, Lipton (2004) argues that the realist can justify at least some *causal-contrastive* IBEs involving unobservable causes on the basis of inductive evidence of our reliability in using these *specific kinds* of IBEs when reasoning about observable causes. The thought is that the relevant IBEs form a sufficiently unified kind of inference, underwritten by the specific kind of explanation involved, to support an inductive projection of our reliability (qua explanatory reasoners) from cases with observable explanans to cases with unobservable explanans. What is clearly important for spelling out a local justification of IBE along these lines is a good grasp on the nature of the explanation at stake. This is one way in which philosophy of explanation interacts with the realist arguments.

Finally, it is worth emphasising that although considerations concerning explanatory reasoning have been central to much of the realist gambit, it would be a mistake to regard all realist arguments as (turning on) IBEs. For instance, Kitcher (2001) develops a quite thoroughgoing (but not global) realist strategy – the so-called 'Galilean strategy' – for delineating the conditions under which we can project the reliability of different modes of reasoning from the observable to the unobservable.[7] Achinstein (2002) has argued that Perrin's theoretical reasoning regarding the reality of atoms exemplifies a realist argument that does not turn on explanatory considerations.[8] Hacking (1982) and Cartwright (1983) have presented local arguments for realism about various kinds of entities on the basis of experiments, independently of explanatory considerations. Although it has been argued that the entity realist arguments are best viewed as ultimately turning on IBE (Reiner and Pierson 1995, Pierson and Reiner 2008), there are also alternative ways of interpreting and precisifying those arguments, turning on a more local conception of what makes particular inductive inferences licit (Saatsi 2009).

4. Explanations' realist commitments

A central question in naturalistic, science-driven philosophy concerns our best scientific theories' realist commitments. If we adopt a realist stance (at least for the sake of the argument), and take seriously the explanatory achievements of science, what exactly are we committed to being realists *about* in the light of our best theories? One influential answer to this question turns on what Stathis Psillos (2005: 389) has called 'the explanatory criterion of reality': "something is real if its positing plays an indispensable role in the explanation of well-founded phenomena".[9] This is certainly a natural starting point for a realist, as it captures the gist of the intuition that explanation is at its heart a *factive* notion: to explain is to get right the relevant explanatory features of reality. If we appeal to some feature of the world as explaining an empirical phenomenon – e.g. to solar flares as the explanatory cause behind an exceptional aurora borealis – presumably we should take as real the feature doing the explaining. And the fact that there are multifarious phenomena that scientists simply cannot

[7] See Magnus (2003) for useful discussion on the limitations of Kitcher's strategy.
[8] See Psillos (2011c) for useful discussion of the role of broader explanatory considerations in the Perrin case.
[9] Psillos finds the roots of this criterion in Sellars (1963), and also notes its affinity to the well-known indispensability arguments of Quine and Putnam.

understand without appealing to, say, electrons, is surely behind scientists' conviction that electrons are real. Electrons play an indispensable role in various scientific theories, furnishing the best available explanations of the relevant phenomena. Realism about electrons follows from taking our best explanations seriously. This is just IBE in action.

So far, so plausible. But the explanatory criterion of reality very quickly leads to head-scratching. For one thing, it is not at all obvious how to square it with the fact that past scientific theories, such as Newtonian gravity, are still broadly taken to be genuinely explanatory of various (e.g. tidal) phenomena (Bokulich 2016). For another, in its simplicity the criterion counsels realist commitment to everything that is indispensable for accepted scientific explanations of empirical phenomena. When one looks at scientific explanations closer, it turns out that they can indispensably involve not only physical posits like electrons, solar flares, and so on, but also *mathematics*, *abstractions* – e.g. average height, or a donut's centre of mass – and *idealisations* – e.g. finite systems being modelled as infinite.[10] It seems that in many cases it is impossible to provide equally good explanations without recourse to abstractions and idealisations. This raises an interesting issue concerning the ontological commitment of such indispensable theoretical posits, assuming we want to infer what is real from our best explanations: taken at face value, the explanatory criterion of reality recommends commitment to abstract things that scientists themselves may casually regard as 'fictional', 'idealized', or as mere mathematical scaffolding needed to provide an explanatory model or derivation of some phenomenon.

Some realists are happy to endorse the face-value upshot of the explanatory criterion: since it turns out that mathematics and other abstracta are explanatorily indispensable for empirical science, our realist commitments should simply be extended to those theoretical posits (e.g. Baker 2009, Colyvan 2013, Psillos 2010, Psillos 2011b). This perspective has an affinity with Quinean confirmational holism, and the so-called 'explanatory indispensability argument' is indeed naturally viewed as an enhancement of the Quine-Putnam indispensability argument for mathematical realism.[11] Others find the extension of realist commitments to abstract objects less palatable, for various reasons. (In particular, there are well-known epistemological worries about abstract objects and mathematical truths.) These philosophers with nominalist sympathies face the challenge of driving a principled epistemological wedge between: (1) those aspects of our best explanations that are in some sense ontologically committing or reality-latching, and (2) those aspects that are merely instrumental – by virtue of playing a merely representation role, say – albeit indispensably so. It can be difficult to do this demarcation without begging some critical questions. For instance, from the perspective of IBE, taken in the abstract, it is unmotivated idea to restrict the explanatory criterion of reality to just *causally* explanatory features of the world – reducing the criterion to the so-called 'Eleatic principle – since arguably there's little to motivate the idea that all our best explanations in empirical science operate in causal terms (cf. Reutlinger and Saatsi 2017). It is also difficult to formally cleanly separate the nominalistic content of scientific theories, so as make sense of their 'nominalistic adequacy' (see, e.g., Psillos 2010).

Nevertheless, I think it would be hasty to accept the face-value upshot of the explanatory criterion. To echo the 'scandal' that Newton-Smith decried years ago (see Section 1), it is

[10] See Mary Leng's 'Mathematical Realism and Naturalism' and Arnon Levy's 'Modelling and Realism: Strange Bedfellows?' (this volume).

[11] While Quine and Putnam emphasised confirmational holism and the role of mathematics for maximising theoretical virtues, the 'enhanced' indispensability argument focuses more specifically on their role in maximising explanatory virtues.

hard to see how we could adjudicate the substantial claims regarding the relation between explanations and ontology without relying on a sufficiently well-developed account of explanation. There is something odd in wholeheartedly advocating the explanatory criterion of reality without backing it up with an account of explanation. If anything, this seems to get things wrong way round. In order to figure out what an IBE commits us to, we presumably first should get a handle on explanatory goodness (in relation to the explanation at stake). And in order to get a handle of explanatory goodness, we presumably need a prior handle on what explaining amounts to. This natural logic suggests that what we need, first of all, is a sufficiently well worked out theory of explanation.

In the light of this it is notable that the extensive debate on explanations' realist commitment has been conducted largely in the absence of (substantial engagement with) well-developed accounts of explanation. And while Newton-Smith perhaps rightly complained about the state of philosophy of explanation at the turn of the millennium, a good deal of progress has been made since, providing us a much better grasp on many relevant aspects of explanation. The realism debate has yet to make full contact with this growing body of work, but recently philosophers have started paying increasing attention to different theories of explanation in assessing the ontological weight of explanatory indispensability (e.g. Baron 2016, Saatsi 2016). Although the jury is still out on the exact realist commitments that genuine explanations should be taken to have, paying due attention to philosophy of explanation certainly indicates as seriously problematic the simple idea that explanations simply wear their ontological commitment on their sleeves.

Thinking about realism in the context of philosophy of explanation raises various interesting possibilities. Consider, for example, the fact that the explanatory goodness of competing explanations is assessed by *us* (human beings). The potential relevance of this fact can be understood in the light of the distinction between *pragmatic* vs. *ontic* aspects of explanation. Explanations and explanatory reasoning can involve pragmatic elements due to the fact that they are communicated, assessed, and understood by us, cognitively finite beings (see e.g. Potochnik 2017).[12] Problematic, purely pragmatic accounts of explanation aside, even if one looks at broadly ontic accounts of explanations – according to which explanations work by identifying explanatory worldly facts – there can be aspects of explanations that play a merely pragmatic or instrumental, as opposed to ontologically committing, factive role. Take, for instance, currently prominent modal accounts of explanation that identify explanations with information about difference-makers (Strevens 2008), or systematic counterfactual variance of the explanandum on the explanans (Woodward 2003). Some aspects of an explanation (or explanatory model) can arguably play an indispensable role in providing us such information in a way that is usable and cognitively salient to us, without figuring as a difference-maker or an explanans variable itself (Saatsi 2016, Baron 2016).

Consider, for example, Euler's graph-theoretic explanation of why the old Koenigsberg's seven bridges could not be traversed without crossing a bridge twice. This is a popular example of a 'distinctly mathematical', non-causal explanation of an empirical phenomenon (Pincock 2007). Appealing to the graph-theoretic notion of a being (non-)Eulerian is arguably indispensable for providing the best explanation of the explanandum at stake. Analysing the explanation in counterfactual terms suggests, however, that what is doing the 'heavy-lifting' in the explanation is the way in which a physical explanandum variable, the bridges'

[12] We can recognise the significance of such elements without drawing a distinction between pragmatic vs. ontic accounts of explanation, which is too black and white.

traversibility, modally depends in a particular way on a physical explanans variable, the number of bridges between the land masses (Jansson and Saatsi, forthcoming). The use of mathematics is indispensable for providing the best, most general explanation of the phenomenon, but mathematics is naturally viewed as playing a merely representational role for capturing the explanatory dependencies between different physical features of the world. In this way, examining questions of explanatory indispensability in the context of modal accounts of explanation can yield more fine-grained distinctions between different kinds of explanatory roles, and thus offer ways of securing the basic realist intuition that genuine explanations are *factive*, while at the same time admitting that not everything involved in an explanation is automatically ontologically committing, even if it is indispensable for the best explanation for us.

Issues concerning explanatory indispensability also spill over to other debates in the metaphysics of science. Certain arguments for ontological *anti-reductionism* (or emergence), for instance, involve appeal to (seemingly) indispensable use of infinite limits in our best explanations of e.g. phase-transitions or universality, allegedly indicating the reality of some emergent, explanatory feature of reality (e.g. Morrison 2012). Reductionists have responded by either denying the indispensability, or by claiming that the explanatory role of infinite limits can be understood in instrumental terms in the light of a closer analysis of the nature of the explanation at stake (e.g. Saatsi and Reutlinger, forthcoming).

5. Conclusion

It seems undeniable that explanation is an important feature of science. Realist philosophers of science often see it as *the* central feature, claiming that scientists often use (implicitly or explicitly) inference to the best explanation as their methodological maxim. Arguing for realism often turns on justifying this kind of method as reliable and truth-conducive. I have argued that there is much to be gained in thinking about these arguments in closer relation to philosophy of explanation. A better grasp on what scientific explanations *are,* and what makes one explanation *better* than another, can throw further light on the viability (or otherwise) of various realist arguments, the nature and reliability of explanatory reasoning, and explanations' realist commitments.

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