How to Reconcile a Unified Account of Explanation with Explanatory Diversity

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Abstract. The concept of explanation is central to scientific practice. However, scientists explain phenomena in very different ways. That is, there are many different kinds of explanation; e.g. causal, mechanistic, statistical, or equilibrium explanations. In light of the myriad kinds of explanation identified in the literature, most philosophers of science have adopted some kind of explanatory pluralism. While pluralism about explanation seems plausible, it faces a dilemma (Pincock 2018). Either there is nothing that unifies all instances of scientific explanation that makes them count *as* explanations, or there is some set of unifying features, which seems incompatible with explanatory pluralism. Different philosophers have adopted different horns of this dilemma. Some argue that no unified account of explanation is possible (Morrison 2015). Others suggest that there is a set of necessary features that can unify all explanations under a single account (Potochnik 2017; Reutlinger 2018; Strevens 2008). In this paper, we argue that none of the features identified by existing accounts of explanation are necessary for all explanations. However, we argue that a unified account can still be provided that accommodates pluralism. This can be accomplished, we argue, by reconceiving of scientific explanation as a cluster concept: there are multiple subsets of features that are sufficient for providing an explanation, but no single feature is necessary for all explanations. Reconceiving of explanation as a cluster concept not only accounts for the diversity of kinds of explanations, but also accounts for the widespread disagreement in the explanation literature and enables explanatory pluralism to avoid Pincock's dilemma.

1. Introduction

Despite much attention in the literature, little consensus about the nature of explanation has emerged. This is because philosophers of science have traditionally focused on attempting to develop universal accounts of explanation. As Melinda Fagan points out:

> Most philosophical discussions of explanation focus on the merits and failings of general accounts, which aim to cover all cases of explanation across the sciences or within a particular field (e.g., physics or neuroscience). The different accounts are considered in isolation, or as opponents. (Fagan 2015, 77)

This approach has led to an ever-expanding list of counterexamples to different universal accounts of explanation. In response to this plethora of counterexamples, the contemporary literature regarding scientific explanation has tended to accept that there is a plurality of types of explanation; e.g. covering law, causal, mechanistic, equilibrium, mathematical, and statistical explanations. In addition, the term 'explanation' is used by scientists to refer to a diverse range of kinds of explanation provided across different scientific disciplines. As a result, most philosophers of science working on explanation have adopted some form of explanatory pluralism.[1] In this paper, we first survey several examples from the explanation literature that demonstrate that there are multiple different kinds of scientific explanation. While this position is not particularly novel, the argument is rarely made explicit by defenders of explanatory pluralism. Moreover, because it is rarely formally presented, it is often unclear just what this argument for pluralism implies for philosophical investigations of the nature of scientific explanation. Most importantly, explanatory pluralism faces a dilemma raised by Christopher Pincock: “The pluralist owes us a discussion of what all explanations have in common and what nevertheless divides these explanations with this common feature into distinct types. Otherwise the common feature threatens to unify explanations into a single type and pluralism of any form is blocked.” (Pincock 2018, 42). In other words, we would like to understand what it is that makes each of these different kinds of explanations all count *as explanations*—i.e. we would like a unified concept of explanation. However, a unified theory that identifies necessary features of all explanations seems to threaten explanatory pluralism.

Several authors in the explanation literature have adopted one or the other of the horns of this dilemma. For example, some authors have suggested that we should focus only on identifying the conditions required for different types of explanation and abandon the quest for a single unified theory of explanation (Lange 2013; Morrison 2015). For instance, Margaret Morrison argues that “neither understanding nor explanation is capable of being codified into a philosophical theory” which is motivated “not only by their susceptibility to counterexamples but by the daunting task of furnishing a theory of explanation that can account for the causal, the structural, and the many other forms that scientific explanations can take” (Morrison 2015, 19). In addition, rather than seeking to provide a unified account of explanation, Marc Lange (2013)

[1] For example, some authors have focused on identifying distinctive features of particular kinds of explanation (Ariew et al. 2015; Batterman and Rice 2014; Lange 2012, 2013; Pincock 2012; Rice 2015; Sober 1983).

argues that there are mathematical and causal explanations that can be distinguished by the scope of the law(s) invoked in the explanation.[2]

In contrast, Reutlinger (2016, 2018) adopts the second horn of the dilemma by arguing that causal and noncausal explanations can be unified under a single theory of explanation focused on counterfactual dependence.[3] That is, Reutlinger argues that providing information about counterfactual dependencies is the necessary feature that unifies all kinds of explanation—what he refers to as explanatory *monism*. As another example, Angela Potochnik (2015, 2017) argues that equilibrium, structural, and mechanistic explanations can all be unified by the fact that they provide information about causal patterns. The goal of these approaches is to identify a set of necessary conditions that unifies all explanations. However, in doing so their accounts seem incompatible with recognizing genuinely distinct kinds of explanation.

In agreement with those that adopt the first horn of Pincock's dilemma, we are sympathetic with the skepticism regarding attempts to provide unified accounts of explanation in terms of necessary and sufficient conditions. However, if we abandon the aim of providing an account of explanation all together, then we will be left without an understanding of why the concept of explanation plays such a central role in scientific inquiry. Explanation is absolutely central to scientific theorizing and plays a crucial role in our everyday reasoning. As Wesley Salmon writes: "Perhaps the most important fruit of modern science is the understanding it provides of the world in which we live, and of the phenomena that transpire within it. Such understanding results from our ability to fashion scientific explanations" (Salmon 1984, 259). We would like some account of what makes certain claims explanatory of the phenomena we

[2] Similarly, Lange (2012) distinguishes really statistical explanations from causal explanations.
[3] Reutlinger's view is similar to counterfactual views defended by Rice (2015) and Saatsi and Pexton (2013) that aim to unify causal and noncausal explanations. However, only Reutlinger argues that a counterfactual account of explanation can unify all explanations under a single account.

observe. That is, we would like an account that is able to: (1) distinguish explanations from non-explanations in a principled way, (2) help us understand why explanations are valuable, and (3) provide normative guidance to scientists who aim to provide explanations.

One might hope that this can be accomplished by adopting the second horn of Pincock's dilemma by attempting to identify a set of necessary conditions that all explanations have in common. However, in this paper, we will argue that none of the features identified by extant accounts of explanation are necessary for all explanations; i.e. there is no unifying feature that all explanations have in common that could provide a robust account of explanation. Our argument for this claim draws from the wealth of counterexamples that have been raised in the explanation literature to various accounts of explanation. As a result of these counterexamples, we argue that it is a mistake to think that a unified account of explanation must be provided by identifying necessary features that all explanations have in common. Therefore, we argue that adopting either horn of Pincock's dilemma results in claims that are at odds with the ways that the concept of explanation is used in science. Scientists routinely refer to very different accounts of phenomena as explanations, but these explanations are so diverse that there is no necessary feature that is common to all of them that can distinguish them from nonexplanations.

In response, we argue that a different approach is required that can avoid the horns of Pincock's dilemma. In particular, we argue that explanation ought to be thought of as a *cluster concept*: it is defined by a list of criteria, such that no one is necessary, but several overlapping subsets are sufficient for membership. The cluster concept approach to explanation aims to strike a balance between being particularists about explanation (i.e. every explanation is different) and the traditional project of identifying conditions that all explanations have in common. Rather than focusing on identifying necessary features common to all explanations, by focusing on various family resemblances (Wittgenstein 1953) between multiple kinds of explanations our account is able to eschew the rigidity of universal accounts and appreciate the variety of ways that scientists explain.[4] On our account, each instance of explanation will instantiate a sufficient subset of the cluster of features that unifies the family, but no one property (or subset of properties) is necessary for membership in the family. One of the primary benefits of this approach is that we can avoid adopting either horn of Pincock's dilemma by providing a unified account that does not depend on necessary conditions for all explanations. Moreover, our account can make sense of the ongoing disagreement about the concept of explanation in the philosophy of science literature.

In order to make the case for thinking of explanation as a cluster concept, the following section surveys various accounts of explanation from the existing literature in order to extract several overlapping subsets of features that are sufficient for providing an explanation. Then, in Section 3, we argue that none of the (subsets of) features are necessary conditions for all explanations. As a result, Section 4 presents our account of explanation as a cluster concept, shows how the account avoids Pincock's dilemma, and how our account helps us understand the persistent disagreement observed in the explanation literature. Finally, Section 5 addresses some possible objections and distinguishes our view from other pluralist accounts in the literature.

2. The Case for Explanatory Pluralism: Multiple Subsets of Sufficient Features

In this section, we survey a number of different accounts of explanation that have been proposed in the literature. The diversity of these kinds of explanation provides a clear case for adopting some kind of explanatory pluralism. Surveying these accounts also allows us to identify several

[4] According to Wittgenstein these family resemblances provide "a complicated network of similarities overlapping and criss-crossing" (*PI* 66).

distinct sets of features that have been taken to be sufficient for providing an explanation. We will take it for granted that each of these accounts captures at least some features of some instances of explanation—although the features specified by some of the accounts may not be sufficient on their own (Bromberger 1966; Gijsbers 2007; Strevens 2008).[5] Our survey of the literature identifies several subsets of features that are sufficient to provide an explanation; e.g. causal, mechanical, statistical, mathematical, and equilibrium explanations. While our presentations of each type of account are brief and the compiled list of accounts is certainly not exhaustive, we think it is unlikely that more detailed descriptions of particular philosophers' accounts would reveal additional conditions that would be necessary or sufficient for *all* explanations.

2.1. Covering-law explanation

According to covering-law accounts, the explanans must contain a set of (true) laws and initial conditions from which the explanandum can be deduced (Hempel and Oppenheim 1948; Hempel 1965). For covering-law explanations, the essential features are that the explanation:

(1) Takes the form of an argument

(2) Cites a law of nature

(3) The explanans is true (or accurate)

(4) Makes the explanandum expected

A classic example of a covering-law explanation would be explaining why a particular spoonful of salt dissolved in water by deducing this fact from the general law that "all salt dissolves in water" and the particular conditions of the salt being placed in the water. Although this account has been extremely influential, several counterexamples have shown that these conditions are not

[5] For example, there are compelling counterexamples that seem to show that Hempel's covering law and unificationist accounts are insufficient on their own.

sufficient to provide an explanation; e.g. the flagpole case and hexed-salt case (Bromberger 1966; Salmon 1984). In response, most philosophers have argued that the flagpole can explain its shadow and the chemical properties of salt explain its dissolving because these explanations meet one of the sufficient subsets of conditions listed below; e.g. they both provide causal explanations.

2.2. Causal explanation

Generally, according to the causal approach, what explains an event is the event's causal history—i.e. the actual causal relationships that produced the explanandum (Salmon, 1984, 1994, 1997).[6] Most causal accounts also involve a temporal component in that a cause must precede its effects. Contemporary theories of causal explanation include Michael Strevens's (2004, 2008) kairetic account, James Woodward's (2003) interventionist account, and Angela Potochnik's (2017) causal pattern account. For causal accounts the key features of an explanation are:

(1) Describes the relevant causes of the explanandum

(2) Provides an accurate description of those relevant causes (i.e. the explanans is true)

(3) Provides information about counterfactual dependence (about how changing the relevant causes would influence the explanandum)

(4) Describes a temporal order of events in the sense that the explanans must occur before the explanandum[7]

As an example of a causal explanation, ecologists might cite the introduction of a particular species as the cause of the extinction of another species. For instance, explaining the extinction of nine of the twelve native bird species of Guam by citing the unintentional introduction of the

[6] In addition, the CM-model was originally proposed by Salmon in 1984, but is similar to the account outlined by David Lewis in his *Causal Explanation* (Lewis 1986) and more contemporary process theories (Dowe 2007).
[7] While this condition is emphasized by process and mechanistic accounts, it is also present in any causal account that requires causes to precede their effects.

brown tree snake (and there being no natural predators of those snakes on the island) (Wright 2008). This explanation accurately describes a previous cause of the event that, if it had not been present (and everything else was held fixed), the explanandum would not have occurred.

2.3. Mechanistic explanation

Mechanistic explanations provide explanations by describing the components, interactions, and processes that produce or give rise to the explanandum. In particular, mechanistic explanations focus on the following features (e.g. Bechtel and Richardson 1993; Craver 2006, 2007; Craver and Darden 2013; Glennan 2017; Kaplan and Craver 2011; Machamer, Darden, and Craver 2000):

(1) Describes the relevant causes of the explanandum
(2) Cites the organization of the parts of the system
(3) Describes a temporal process that unfolds from start-up to termination conditions
(4) The explanans must be true (or accurate)
(5) Provides information about counterfactual dependence (about what would happen if the parts, interactions, or initial conditions had been different)

For example, an engineer might explain the motion of a bicycle by citing the temporal processes that unfold in the mechanism(s) that relates the various parts of the bike's drivetrain (Glennan 2017). Such a mechanistic explanation might describe the detailed steps for how the crankset drives the freewheel via the chain.

2.4. Unificationist explanation

The central idea behind the unification approach is that explanation is a matter of providing a unified account of a wide range of different phenomena (Friedman 1974; Kitcher 1981; Kitcher 1989). The features emphasized by unificationist theories are:

(1) Connects disparate phenomena

(2) Is general

(3) Appeals to laws or sufficiently invariant generalizations

(4) The explanans must be true (or accurate)

For example, the theory of evolution explains the diversity of forms of life found on earth by citing the generally applicable pattern of natural selection (Kitcher 1981). While some unificationist accounts also include providing a deductive argument that entails the conclusion (Kitcher 1981), not all unificationist accounts include this feature. Furthermore, some philosophers have argued that this set of features is not sufficient to provide an explanation on its own (Gijsbers 2007). While these features may not be sufficient on their own to provide an explanation, the features of unificationist accounts have been extremely influential for many contemporary accounts of explanation (e.g. Potochnik 2017; Strevens 2004, 2008; Woodward 2003).

2.5. Equilibrium explanation

In cases of equilibrium explanation, the final state of a system is explained by showing that it is the system's equilibrium state (Potochnik 2007, 2017; Rice 2012, 2015; Sober 1983). These explanations emphasize the following features:

(1) Makes the explanandum expected

(2) Appeals to structural features (e.g. constraints and tradeoffs) of the overall system

(3) Provides information about counterfactual dependence

For example, many philosophers discuss Fisher's use of an equilibrium model to explain the ubiquity of the 1:1 sex ratio (Maynard Smith 1982; Potochnik 2017; Rice 2015; Sober 1983). In this case, Fisher argues that anytime one sex is in the minority, offspring of the minority sex will have a fitness advantage due to increased mating opportunities. As a result of this structural feature of the overall system, the system will eventually move to a 1:1 equilibrium sex ratio.

2.6. Mathematical explanation

In addition, many authors have argued that there are distinctively mathematical explanations (Baker 2009; Lange 2012; Pincock 2012). These accounts emphasize the following features:

(1) Appeals to mathematical facts

(2) The explanans is true (or accurate)

(3) Provides information about counterfactual dependence (e.g. about how changing the mathematical facts would change the explanandum)

For example, we can explain why it is impossible for Mother to divide 23 strawberries evenly among her five children by appealing to the mathematical fact that 23 does not divide evenly by five (Lange 2012).

2.7. Statistical explanation

Another kind of explanation involves appealing to statistical properties of a system (Ariew, Rice and Rohwer 2015, 2017; Lange 2013; Matthen and Ariew 2009; Walsh et al. 2002; Walsh 2007, 2010). Such statistical explanations often involve deduction from laws that govern statistical distributions—e.g. the law of deviation. A statistical explanation:

(1) Cites statistical features of the population

(2) Cites statistical laws

(3) Provides information about counterfactual dependence (e.g. about what would occur if the statistical features of the population had been different)

As an example, several accounts discuss Francis Galton's use of statistical regression to explain the stability of the distribution of character traits (e.g. height) across generations of a population

(Ariew et al. 2015). Galton used the statistical law of deviation to derive that if a population were normal distributed in the initial generation, then the next generation would also display a normal distribution.

This survey does not exhaust all potential accounts of explanation, but we think it captures several of the most influential ones. What the above accounts show is that philosophers have already done a fairly decent job of identifying a range of subsets of features, many of which are sufficient for explanation; e.g. causal, mechanical, equilibrium, mathematical, or statistical explanations. A satisfactory account of explanation must account for this diversity of kinds of explanation found in science.[8]

3. None of These Features Are Necessary for Explanation

The most common response at this point has been for philosophers of science to try to identify a set of features that are necessary for each of the various kinds of explanation. The hope is that identifying these necessary features will enable us to provide a unified account of explanation that can subsume the diverse types of explanation found in science. In contrast to this approach, we argue that *none of the features identified by these accounts of explanation are necessary conditions.* To begin, we assume that any feature that shows up on only one of the lists above is not necessary for all explanations since there are clearly other kinds of explanation that do not require that feature. This rules out the following features as necessary conditions:

(1) Takes the form of an argument

(2) Cites the organization of parts of the system

(3) Appeals to a mathematical fact

[8] For our purposes here, we will not be defending accounts of any of the particular kinds of explanation identified here. We only assume that some of these lists of features are sufficient to explain.

(4) Cites statistical features of the population

(5) Is general

(6) Connects disparate phenomena

(7) Appeals to structural features of the overall system

The remaining features that occur on more than one list are the following:

(1) Provides information about counterfactual dependence

(2) Cites causes of the explanandum

(3) Describes a temporal order of events

(4) Cites a law

(5) Makes the explanandum expected

(6) The explanans is true or accurate

In the rest of this section we will argue that, while they are common features of many explanations (i.e. they are resemblances among members of the family), none of these features are necessary conditions for all explanations.

To begin, providing information about counterfactual dependence is found across numerous kinds of explanation (Bokulich 2011; Reutlinger 2018; Rice 2015; Woodward 2003). However, there are a few instances in which an explanation can be given where information about counterfactual dependence is not necessary. Specifically, we have in mind certain cases of preemption or overdetermination where the explanation cites a cause of the explanandum, but the explanandum does not counterfactually depend on that cause because, if the cause had not occurred, another cause would have made the explanandum happen anyway. For example, if a teacher wants to explain why the classroom window is broken, for purposes of assigning blame, she can cite the fact that Julie threw a rock at the window as the explanation. However, if Julie had not thrown the rock, then the window still would have broken since Michael also threw a rock at the window that arrived shortly after Julie's. In this case, the teacher's explanation is sufficient for her purposes in virtue of citing the actual cause of the explanandum, but the explanation does not cite any features on which the explanandum counterfactually depends. As a result, this kind of case illustrates that information about counterfactual dependence is not necessary to provide an explanation.

A defender of the necessity of counterfactual dependence for explanation might respond that while the statement 'Julie threw a rock' does not cite a feature on which the explanandum counterfactually depends, there is a larger network of counterfactual relations that includes the counterfactual dependence between the fact that 'someone threw a rock' and the explanandum and this larger network must be cited in order to adequately explain. However, while there certainly is a counterfactual dependence explanation that might cite someone's throwing a rock as the reason for the window's breaking, the teacher's original explanation that only cites Julie's rock as the cause of the window's breaking seems sufficient without having to include this further information about counterfactual dependence. Moreover, certain contexts in which this kind of explanation might be sought—e.g. a teacher wanting to know *who* broke the window—would require that the explanation be more specific than merely citing the generic counterfactual dependence between someone's throwing a rock and the window's breaking. Indeed, what the context seems to require is that the explanation cite the specific cause of the window's breaking (Julie's throwing of the rock) on which the explanandum does not counterfactually depend.

Woodward argues that cases of preemption are not problematic for his interventionist view of explanation since everyone will agree about what the relevant counterfactuals are in these kinds of cases (Woodward 2003, 85-86).[9] In order to argue for this point, Woodward discusses a slightly different kind of case in which, had the first cause not occurred, then the second cause would have occurred (but the second cause did not occur in the actual case). Woodward then suggests that if we hold fixed the actual situation, in which the second cause fails to occur, then the effect *does* counterfactually depend on the occurrence of the first cause (Woodward 2003, 86). However, the case described above is importantly different. In particular, in the case described above *both* of the (potential) causes of the event occur. As a result, if we hold fixed the actual situation in which Michael throws a rock, then the window's breakings *does not* counterfactually depend on Julie's throwing of a rock.

In addition, we agree with Woodward that we can all agree what the counterfactual dependence relations would be in these cases if they were represented by an idealized causal model. However, given the context of the explanation in which a teacher wants to know who broke the classroom window for purposes of assigning blame, it appears that the teacher only needs to cite that Julie's rock broke the window in order to explain—even if the teacher is completely ignorant of the counterfactual dependencies that might hold in an idealized causal model (Woodward 2003, 85).[10] In short, the teacher does not need to cite any counterfactual dependencies; her explanation is sufficient despite citing a feature on which the explanandum does not counterfactually depend in the actual case. This is similar to several cases described by Khalifa et al. (forthcoming) in which one can find some kind of counterfactual dependence, but that counterfactual information is 'incidental' to the actual explanation—i.e. the explanation can

[9] Somewhat similarly, Lewis (2000) argues that preemption cases can be captured by counterfactual accounts (of causation) by suggesting that there will counterfactual dependencies between certain whether, when and how the cause occurs and whether, when and how the effect occurs. This might be so even if some of those changes to the cause fail to change the occurrence of the effect.

[10] What is more, assuming that Michael does not throw a rock in order to evaluate the counterfactual relations between Julie's throwing a rock and the breaking of the window just removes the preemption from the scenario in order to establish a counterfactual dependence between Julie's throwing the rock and the window breaking.

be provided independent of that counterfactual dependence. In other words, even though there might be some truths about counterfactual dependencies in every case, it does not follow that it is necessary to cite those counterfactual dependencies in order to provide an explanation.[11] We argue that the preemption case above shows that, in at least some cases, citing a relationship of counterfactual dependence is not necessary to explain.

Next, the citing of causes to explain is widespread in science. However, there are several instances of noncausal explanation that have been analyzed in the literature in which a causal interpretation of the explanatory variables is inappropriate. For example, mathematical properties (Pincock 2012), statistical properties (Ariew et al. 2015, Lange 2012, 2013; Walsh et al. 2002), or tradeoffs among structural features (Rice 2012, 2015) can all be used to explain without having to cite the causes of the explanandum. As an example, consider again the explanation for why it is impossible for Mother to divide 23 strawberries evenly among her five children. This explanation cites only mathematical facts about the indivisibility of 23 by 5 without citing any causes of the explanandum (Lange 2012).[12] Consequently, assuming that at least one of these noncausal cases is a genuine instance of explanation, citing causes is not necessary to provide an explanation.

In addition, while most causal and mechanistic explanations cite a temporal order of events in which the causes precede the effects, some explanations lack this temporal feature and instead explain things *synchronically* (Pincock 2012; Rice 2012).[13] For example, mathematical explanations of why it is impossible to cross all the bridges of Köningsberg only once without

[11] Thanks to two anonymous reviewers for encouraging us to make this line of argument more explicit.
[12] It is also worth noting that, similar to our response to the preemption cases above, Lange (2012) argues that although there is causal information available in this case, that causal information is incidental to the explanation.
[13] It is worth noting that at least some mechanistic explanations are constitutive explanations that seem to be synchronic rather than diachronic (Craver 2006). However, as we will argue below, we think this is just further evidence that citing a temporal order of events is not necessary for all explanations. Thanks to an anonymous reviewer for bringing this other kind of synchronic explanation to our attention.

crossing the same bridge twice need only cite the fact that the bridges form a non-Eulerian graph (Pincock 2012). As Pincock notes, "it seems clear that our representation of the bridges is not a causal representation for the simple reason that it does not represent change over time" (Pincock 2012, 53). Therefore, citing a temporal ordering of events is likewise not necessary to explain.

The next feature of many explanations is the citing of laws. However, as much of the literature in philosophy of biology and philosophy of the social sciences has shown, there are large parts of science that do not have laws—or at least are able to explain without having to cite laws. While many explanations appeal to generalizations, it seems clear that these generalizations need not count as laws of nature (however they are defined) in order to provide an explanation. As a result, citing a law of nature is not necessary for all explanations.

Another feature that many accounts appeal to is the fact that the explanans makes the explanandum expected (Batterman 2002; Hempel 1965; Rice 2015). However, there are many cases in which a sufficient explanation is provided for a highly improbable event. When this happens, the explanans shows that the phenomenon was *unexpected* because it was highly unlikely. However, the explanans can still show why the phenomenon occurred even if it was improbable. For example, we can explain a run of 100 heads in a series of coin flips by citing the propensity of the fair coin even though that explanation shows why the explanandum is improbable or unexpected.

Finally, almost all accounts of explanation suggest that the explanans must be true or accurate. For example, Hempel required the premises of the explanatory argument to be true and most causal accounts (e.g. Strevens 2008) require the explanation to accurately describe (or represent) the relevant causes of the explanandum. Hence it has been suggested that the explanatorily relevant features must be accurately described by the propositions or representations included in the explanans. However, several recent accounts of how highly idealized models explain allow models that include essential idealizations (i.e. ineliminable false assumptions) to provide sufficient explanations (Batterman 2002; Batterman and Rice 2014; Bokulich 2011, 2012; Morrison 2009, 2015; Rohwer and Rice 2016; Rice 2015, 2017). For example, physicists use the lattice gas automaton (LGA) model as part of the explanation of the universal macroscale behaviors of fluids despite the model being a caricature of any real fluid (Batterman and Rice 2014). The model misrepresents fluids as discrete systems composed of point particles that only interact according to a simple computational algorithm. Moreover, the explanation of the universality of these patterns of fluid flow makes use of renormalization group techniques that require an essential idealization known as the *thermodynamic limit*: the limit in which the number of particles in the system goes to infinity (Batterman 2002; Batterman and Rice 2014).[14] Without this idealization, the mathematical representations appealed to in the explanation do not display the kinds of behaviors (e.g. phase transitions) physicists are interested in explaining (Batterman 2002; Batterman and Rice 2014; Morrison 2015). As Margaret Morrison explains:

> The occurrence of phase transitions requires a mathematical technique known as taking the 'thermodynamic limit,' $N \rightarrow \infty$; in other words we need to assume that a system contains an infinite number of particles in order to understand the behavior of a real, finite system…[since] the assumption that the system is infinite is *necessary* for the symmetry breaking associated with phase transitions to occur. In other words, we have a description of a physically unrealizable situation (an infinite system) that is *required* to explain a physically realizable phenomenon (the occurrence of phase transitions). (Morrison 2009, 128).[15]

[14] While Lange (2014) and Povich (2018) have raised various objections to Batterman and Rice's (2014) account of minimal model explanations, they do not disagree with the claim that the explanation that appeals to renormalization requires the thermodynamic limit. While we disagree with many of the criticisms raised by those authors, we don't think this paper would be well served by getting into a more detailed debate about how minimal model explanations work given that all parties agree to the essential use of idealizations in these explanations. Indeed, the essential use of idealizations within explanations has been widely adopted by many authors who have focused on cases besides minimal model explanations (e.g. see Batterman 2002; Morrison 2015; or Wayne 2011). Our point here isn't that these explanations provide no accurate information, but that they necessarily require a falsehood. As a result, we use the example to show that being completely true/accurate is not a necessary condition for all explanations.

[15] Or as physicist Leo Kadanoff (2000) puts it, "The existence of a phase transition requires an infinite system. No phase transitions occur in systems with a finite number of degrees of freedom" (238).

In short, these explanations in physics distort many of the difference-making features of real fluids and depend in essential ways on idealized limits (that cannot be true in the actual case). If these cases of essential idealizations provide sufficient explanations—which many philosophers and physicists argue that they do—then complete truth or accurate representation within the explanans is not necessary for explanation either.[16]

We have now argued that none of the features identified by the most prominent accounts of explanation are necessary conditions. Once we recognize this fact, we can see why the explanation literature is filled with an ever-expanding list of counterexamples to accounts of explanation that claim a particular subset of conditions is sufficient *and necessary* to provide an explanation. One might think that this entails that philosophers should abandon attempts to provide a unified account of explanation; i.e. they should adopt the other horn of Pincock's dilemma. However, in the next section, we argue that a unified account can still be provided that accommodates explanatory pluralism.

4. Explanation as a Cluster Concept

Given that the concept of explanation is central to scientific practice, philosophers have long sought to provide a unified account of scientific explanation (Salmon 1989). However, as we saw in Section 2, scientists explain phenomena in very different ways. A common response has been to try to identify a set of necessary features that could unify all explanations. However, as we argued in Section 3, none of the features identified by extant accounts are necessary for all explanations. This raises the worry that it may not be possible to provide a unified account of

[16] There is a crucial difference here between arguing that explanations can involve essential idealizations and suggesting that explanations need not involve any truths. We argue only that it is not necessary for an explanation to contain only true statements. Moreover, we address the possibility that all explanations must involve *some* truth in Section 5.2.

explanation. Hence, philosophers of science have recently focused more on demarcating different kinds of explanations from one another (Ariew et al. 2015; Bokulich 2012; Lange 2012, 2013; Sober 1983; Walsh et al. 2002). In contrast, we argue that a unified account of explanation can still be provided, but to do so we must move beyond attempting to find necessary features of all explanations. This can be accomplished, we argue, by reconceiving of scientific explanation as a cluster concept: there are multiple subsets of features that are sufficient for providing an explanation, but no single feature is necessary for all explanations. In support of this view, we argue that reconceiving of explanation as a cluster concept accommodates the diversity of kinds of explanation, accounts for the widespread disagreement in the explanation literature, and enables explanatory pluralism to avoid Pincock's dilemma.

If explanation is a cluster concept then there ought to be a set of features, several overlapping subsets of which are sufficient to explain, but none of which are necessary for all explanations. We think the various accounts of explanation from the last 70 years (surveyed in Section 2) give us a robust start for formulating this list of features. Moreover, these various accounts of scientific explanation have shown that various subsets of these features are sufficient to provide different kinds of explanation. Finally, while we have argued that none of these features are necessary for all explanations, the subsets of sufficient features have significant overlap. We summarize these results in the table below.

Accounts of Explanation	Covering-law	Causal	Mechanistic	Unificationist	Equilibrium	Mathematical	Statistical
Features of Explanations							
Takes the form of an argument	x						
The explanans is true (or accurate)	x	x	x	x		x	x
Cites the organization of parts of the system			x				
Describes a temporal order of events		x	x				
Cites laws	x			x			x
Connects disparate phenomena				x			
Appeals to a mathematical fact						x	
Cites statistical features of a population							x
Is general				x			
Appeals to structural features of the system					x		
Provides information about counterfactual dependence		x	x		x	x	x
Cites of causes of the explanandum		x	x				
Makes the explanandum expected	x				x		

As this table illustrates, various overlapping features can connect diverse members of the family of explanations. In fact, every kind of explanation shares at least some features with at least one other kind of explanation. Therefore, while there are no necessary features common to every explanation, every kind of explanation is connected via certain resemblances with other members of the family. For example, providing counterfactual dependence information is common to many forms of explanation. Similarly, truth and accuracy is common to many kinds of explanation. In addition, describing a temporal order of events connects causal and mechanical forms of explanation. What this shows is that the sufficient subsets for explanation overlap in significant ways that enable us to discover connections between different kinds of explanation. Despite the diversity of features and kinds of explanation, reconceiving of explanation as a cluster concept enables us to recognize these significant overlaps and maintain a unified concept of explanation without having to discover necessary features of all explanations.

Conceiving of explanation as a cluster concept also enables us to provide an account of what makes explanations epistemically valuable to scientists. In particular, explanations are epistemically valuable because they have some subset of the features in the list above. For example, having a causal explanation is valuable because it describes the causes of the explanandum, describes relationships of counterfactual dependence, describes how a temporal order of events unfolds, and is true of the causal structure of the world. However, while all explanations are epistemically valuable because they provide information that scientists desire, the source of that value will be different for different kinds of explanation. For example, a statistical explanation will be valuable because it describes statistical properties, describes statistical laws, describes counterfactual dependencies, and these features are true of the systems in which the explanandum occurs. Ultimately the reason these kinds of information are valuable is because they are valuable to practicing scientists who have different interests and goals (Woody 2015).[17] In short, the reason explanations are valuable is not because they all provide the same types of information, but because the different types of information they provide are able to satisfy the varying interest of practicing scientists.

Our approach abandons the long history of philosophical attempts to analyze the concept of explanation in terms of necessary and sufficient conditions. However, proposing that explanation is a cluster concept is not to abandon the project of trying to analyze the concept. Instead, cluster concepts provide some rules about how the concept can be appropriately applied—they simply allow that the same concept can be appropriately applied in several overlapping ways (Pigliucci 2003). As Wittgenstein puts it: “We can draw a boundary for a special purpose. Does it take that to make the concept usable? Not at all!’’ (PI §69). For example, Wittgenstein argues that while some things are games and some are not, this is consistent with there being indeterminacy about precisely where those boundaries are. In other words, concepts can still be usable even if their boundaries do not have the precision provided by

[17] An anonymous reviewer suggested that perhaps a necessary feature of all explanations is that they provide information about the world. However, we think this feature is insufficient to distinguish explanations from non-explanations. After all, many things provide information about the world without explaining. Moreover, we think it is important to recognize that the reason explanations are valuable is because they provide the kinds of information about the world that are valuable to scientists—i.e. explanations are valuable because scientists find them valuable not just because they provide information.

necessary and sufficient conditions (e.g. heaps and baldness). What is more, we suggest that this lack of precision of the boundaries of the concept accounts for the widespread disagreement found in the explanation literature. As we saw in Section 2, the philosophical literature on explanation has resulted in numerous accounts of explanation that are seemingly incompatible with each other. Moreover, because these accounts have proposed necessary and sufficient conditions, the literature on explanation also contains an ever-expanding set of counterexamples to the proposed universal accounts. This proliferation of counterexamples is precisely what one would expect if none of the features of explanations are necessary for all explanations. Because no feature is necessary, there will always be a counterexample to any proposed necessary condition. Moreover, given that there are multiple sufficient subsets for explanations, in many cases we should not expect these disagreements to be resolved. After all, defenders of different accounts, or counterexamples to those accounts, will often simply be making use of different subsets of sufficient features. Consequently, our account can explain the vast and heated disagreement in the philosophy of science literature on explanation.[18] What is more, our account points to a way to move the discussion of scientific explanation beyond these intractable disagreements. Reconceiving of explanation as a cluster concept would encourage philosophers of science to focus on identifying a range of sufficient types of explanation, where those types of explanation are typically found, as well as identifying what different kinds of explanation might have in common. Moreover, by identifying new kinds of explanation, we can expand the list of features that unify the family of explanations together.

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[18] Moreover, if our account is correct, then we can provide an explanation for why the psychology of explanation literature suggests that there are multiple concepts of explanation employed in our everyday reasoning (Columbo 2017). That different philosophical theories of explanation all track some cases of our judgments of explanatory power is just what one would expect if explanation is a cluster concept.

Conceiving of explanation as a cluster concept also shows a way for explanatory pluralists to avoid Pincock's dilemma. Recall that Pincock's dilemma is that either the pluralist needs to abandon any attempt to provide a unified account of explanation, or they must identify unifying features, which seems incompatible with genuine pluralism about explanation. Instead of adopting either of the horns of this dilemma, we have argued that a unified account of explanation can be provided without having to identify necessary features that all explanations have in common. This is accomplished by recognizing that a unified account is obtainable without referencing any particular feature as necessary or common to all instances. What unifies these diverse cases under the moniker of 'scientific explanation' are the various overlapping features or resemblances between members of the family of explanations found in science. Like other possible applications of cluster concepts (e.g. species), this enables us to account for the diversity of features of individual members of the family, while maintaining that the connections between them are able to distinguish them from nonmembers. That is, rather than just having a few minor connections between family members, the substantial overlap of many features of the members is robust enough to make normative application of the concept possible. In this way, reconceiving of explanation as a cluster concept allows us to recognize the myriad different ways that scientists explain and yet maintain a unified account of scientific explanation.

5. Objections and Replies

5.1. Ruling Out Nonexplanations

One possible objection to thinking of explanation as a cluster concept is that the concept might be so inclusive that it allows in typical cases of intuitively nonexplanations. However, this is not the case. To propose that explanation is a cluster concept is only to suggest that there are multiple overlapping sufficient subsets of features none of which are necessary. This is compatible with several purported cases failing to meet any of the sufficient subsets of features. Moreover, purported accounts of explanation might be wrong about the sufficiency of the conditions they cite and the cluster concept should be refined accordingly. For example, cases like the flagpole or hexed salt showed that meeting Hempel's list of conditions was insufficient for providing an explanation. Furthermore, these cases fail to meet all the other proposed sets of sufficient conditions as well. Therefore, these cases show that a cluster concept can still be used to demarcate genuine explanations from nonexplanations. Interestingly, most of the explanation literature has focused on demonstrating that a particular set of criteria is not *necessary* for providing an explanation. However, we have argued that the counterexamples from the explanation literature suggest that *no feature* is necessary for all scientific explanations. As a result, we contend that the analysis of scientific explanation should shift its focus to the subsets of conditions that purport to be *sufficient* for scientific explanation in order to determine if they really are sufficient on their own. Doing so will help us refine our proposed reformulation of explanation as a cluster concept and help us discover if particular instances are, in fact, genuine explanations or nonexplanantions.

5.2. Necessary Features of All Explanations are Cheap

Another possible objection is that, of course there are several features that all explanations have in common that might be cited as necessary features for being a scientific explanation. For example, one might suggest that all explanations are answers to why questions (van Fraassen 1980). After all, what distinguishes explanations is that they show us why the explanandum occurred. In addition, one might point out that all explanations involve some true statements.

However, while many features will be common to all explanations, citing such generic features as necessary conditions provides little in terms of an account of what makes something an explanation. That is, whatever set of trivial features might be common to all explanations will be insufficient to generate anything like a normative account of the nature of scientific explanation that could help us understand why explanations are epistemically valuable. This is precisely why our account builds on the sets of sufficient conditions already identified by extant accounts of explanation. These accounts can provide normative guidance for practicing scientists and enable us to distinguish between different kinds of explanation. It is only by incorporating the more specific features of various kinds of explanation that we get a more robust account of what enables the features cited in the explanans to explain why the explanandum occurred.

Another way to see why the features that all explanations have in common will be insufficient to provide a satisfactory account of explanation is to consider what Andrea Woody (2015) calls the functional role of explanations in science. Woody argues that the epistemic value of explanations is captured by their playing a particular functional role: they contribute to advancing the research programs they are part of by organizing (or structuring) the way in which those research programs ought to be pursued. In particular, Woody argues that "Explanatory theories are ones from which scientists can develop rich explanatory practices that effectively establish communal norms for reasoning that in turn facilitate achievement of the community's cognitive and epistemic aims" (Woody 2015, 86).[19] We agree that any account of explanation ought to be able to account for this functional role of explanation in scientific practice. Indeed, accounting for this role is crucial to showing why explanations are epistemically valuable to scientists. The common features discussed above, however, fail to do this. For example, merely

[19] For example, Woody suggests that explanation "enforces communal norms regarding what sorts of information are to be considered intelligible and enlightening and the types of reasoning that are legitimate within the community" (Woody 2015, 86).

saying that explanations involve some truths or that they answer why questions, fails to tell us why (or how) explanations are particularly valuable to scientific practice.

5.3. How is the cluster concept account different from other pluralist proposals?

A final kind of objection suggests that other philosophers of science have already proposed similar kinds of explanatory pluralism. First, as we noted above, both Pincock and Reutlinger have argued that various kinds of explanation might be unified under a single account. For Pincock this is accomplished by arguing that various kinds of explanation all involve some kind of ontological dependence where the way the contrastive why question is asked determines which of the ontological dependence relations ought to be appealed to in the explanation (Pincock 2018). The key point, for Pincock, is that by contrasting the explanandum in different ways, we can avoid having to claim that there are multiple dependence relations that explain the same fact, which would generate an 'overdetermination problem' for ontic accounts that appeal to dependence relations in the world. Instead of having multiple dependence relations explain the same explanandum, Pincock suggests that different dependence relations will be suited to answer different contrastive questions (Pincock 2018, 51).[20] In sum, according to Pincock we can accommodate explanatory pluralism by showing that all explanations must involve some kind of dependence relation, but different dependence relations ought to be used in order to answer different contrastive why questions.

While we agree with Pincock that the way in which the why question is asked and contrasted will greatly influence the kind of explanation that ought to be provided in a particular

[20] For example, Pincock argues that "when a contrast is tied to a difference that could have been made through causes changing events, while fixing the constitutive character and the broader abstract structure, then a causal explanation in mandated…when a contrast invokes a difference between types of systems, then only an abstract explanation will cite the right kind of factor that is responsible for those differences across systems. Looking at the operations of causes or the internal constitution of the elements of the actual system will fail to make sense of that sort of contrast" (Pincock 2018, 51-52).

context, we think merely appealing to dependence relations fails to provide an adequate account of what explanations are and why they are valuable. Indeed, in many ways the key question regarding explanations is precisely *which* dependence relations can be used to explain and why uncovering those dependence relations is valuable to scientists. We contend that it is in virtue of their ability to satisfy a sufficient subset of the criteria involved in our cluster concept that shows why various kinds of dependence relations are able to provide explanations. That is, merely appealing to the fact that all explanations involve dependence relations is too thin to provide a complete account of explanation that could provide normative guidance and capture what is distinctively valuable about explanations.[21] In contrast, by revealing the various subsets of features that different kinds of explanations (i.e. those that appeal to different dependence relations) are able to provide, the cluster concept account fills in what distinguishes explanations and makes them particularly valuable.

In a similar way, following Bokulich (2012), Rice (2015), and Saatsi and Pexton (2013), Reultinger (2016, 2018) argues that multiple kinds of explanations can all be subsumed under a counterfactual account of explanation. While we are sympathetic with this approach's attempts to unify causal and noncausal explanations by appealing to counterfactual dependence, as we argued above there will be cases where the features appealed to in the explanans are features on which the explanandum does not counterfactually depend. Another problem with Reutlinger's monistic account is that he suggests that all explanations must appeal to 'nomic generalizations' (Reutlinger 2018, 79), but we have argued that such appeals to law-like regularities are not necessary for all explanations. Finally, Reutlinger argues that all the generalizations and conditions appealed to in an explanation must be veridical or true (Reutlinger 2018, 79).

[21] There is, of course, much more to Pincock's account of explanation. However, our focus here is on the feature he proposes as being the unifying feature of all explanations.

However, this necessary condition fails to hold in cases where essential idealizations play a role within the explanation (Batterman 2002; Batterman and Rice 2014; Khalifa et al. forthcoming; Morrison 2015). In short, Reutlinger's account cannot accommodate instances where falsehoods play essential and ineliminable roles within the explanation; e.g. the essential use of the thermodynamic limit in renormalization explanations.[22] Reutlinger responds to this challenge by suggesting that idealized explanations can be covered by a minimalist account of idealization (e.g. that proposed by Strevens 2008) in which idealizations distort non-difference-making (i.e. irrelevant) features (Reutlinger 2018, 80). However, there are many explanations, such as the renormalization group explanation described above, in which the idealizations play essential roles within the explanation and cannot be restricted to the distortion of irrelevant factors (Batterman 2002; Rice 2017, 2018). In these cases, features of the system that are known to make a difference and on which the explanandum counterfactually depends are distorted within the explanans. Consequently, there are several cases of explanation that cannot be accommodated by Reutlinger's veridicality condition even if we adopt a minimalist account of idealization. In sum, we think the arguments given above show that at least three of the conditions involved in Reutlinger's account are not necessary for all explanations.

Next, our account agrees with Woody (2015) that an account of explanation ought to capture the functional role that explanations play that makes them epistemically valuable to the practice of science. Moreover, like Woody, we have argued that looking to scientific practice reveals extreme heterogeneity with respect to the ways that scientists explain. We also think our account provides many of the same virtues Woody claims for the functional perspective; e.g. a

[22] While Reutlinger (2016) argues that his account can accommodate RG explanations, we think his presentation of that case rests on a misunderstanding of the crucial role played by the thermodynamic limit in allowing the renormalization transformation to arrive at a fixed point which enables physicists to identify the critical exponents that are essential to explaining the universality of the critical behaviors we observe. Rather than working through those details here, we refer interested readers to Batterman (2002, 2010) and Morrison (2009, 2015).

focus on actual scientific practice, the ability to accommodate explanatory pluralism, the ability to account for the explanatory status of idealized models, and the ability to salvage various insights from the existing explanation literature.[23] However, while Woody argues that we need to consider how explanations contribute to the aims of scientific practice, she does not offer this as a unifying account of what distinguishes explanations from nonexplanations. Indeed, as Woody notes, "Even if one adopts the functional perspective, there is still a significant project characterizing the adequacy conditions applied to particular explanations in particular contexts." (Woody 2015, 86). We think our account of explanation as a cluster concept does precisely this: it analyzes the similarities and differences of the adequacy conditions used across different cases from scientific practice. Filling in these details also seems to help address some of the concerns Woody raises for the functional perspective; e.g. the inability to judge which explanations are adequate or the difficulty of distinguishing explanations from nonexplanations. In particular, our account of explanation as a cluster concept fills in additional details about precisely *which* aims of scientific practice different kinds of explanations are able to contribute to. In sum, we think our approach is consistent with Woody's functional perspective, but is distinct in aiming to provide a unified account of explanation that can accommodate the plurality of ways that scientists explain, demarcate explanations from nonexplanations, and provide additional details about why explanations are valuable to practicing scientists.

Finally, Eric Hochstein has admirably tried to make sense of the disagreements in the explanation literature by distinguishing several different goals of explanation and arguing that the disagreements result from different authors focusing on different goals. In light of these different goals, Hochstein's main thesis is that, "Given that no one model can satisfy all the goals

[23] We also think our account connects explanations with understanding; e.g. see Rohwer and Rice 2016 for a more detailed discussion of those connections.

typically associated with explanation, no one model in isolation can provide a good scientific explanation of a complex phenomenon" (Hochstein 2017, 1107). As a result, Hochstein argues that, "Collections of models provide an explanation when they satisfy the web of interconnected goals" (Hochstein 2017, 1122).

While both Hochstein and we lay out various features of different types of scientific explanation, the view we adopt in response to the diversity of those goals is very different. First, where Hochstein explicitly rejects that satisfying a subset of these goals is sufficient to explain, we explicitly adopt this kind of pluralism and have tried to show how it can be made compatible with providing a universal account of what makes explanations distinct and valuable. However, unlike Hochstein's description of pluralism, we do not think that the pluralist is required to "determine a clear victor between conflicting explanatory goals so as to grant one model or another the status of an explanation" (Hochstein 2017, 1115). Instead, the kind of pluralism we embrace allows that there will often be multiple sufficient explanations for the same phenomenon where no one of the explanations should be declared the 'victor'.

Second, where Hochstein argues that no single model can provide an explanation (2017, 1120), we contend that many single models are sufficient to explain because the information they provide will satisfy a sufficient subset of the conditions included in the cluster concept. Indeed, many of the examples provided above involve single models that are able to provide sufficient explanations. Whereas Hochstein's account would require us to radically reconceive of each of these cases as failing to explain without additional models that could satisfy other goals (e.g. describing mechanisms), we think these models are sufficient to explain on their own—even if other models are required to achieve other explanatory goals or provide different explanations. As a way of clarifying this crucial difference, consider Hochstein's claim that no explanation can be provided unless one of the models involved is able to describe the "physical mechanisms that generate and sustain the target phenomenon" (Hochstein 2017, 1106). We disagree. In contrast, we think many (individual) models are able to provide scientific explanations without requiring that they, or some other model, satisfy all the other goals on Hochstein's list; e.g. describing the mechanisms that gave rise to the phenomenon. While mechanistic explanation is certainly one form of explanation, as we have argued above, describing a mechanism is not necessary to explain.

This draws out the starkest contrast between our view and the view defended by Hochstein. Where Hochstein argues that it is necessary for a collection of models to satisfy *all* of the goals he thinks are traditionally associated with explanations in order to explain, we have argued that *none* of the conditions traditionally associated with explanation are necessary. For example, Hochstein's view requires that all explanations must describe mechanisms and enable for manipulation and control.[24] In contrast, we do not think that all explanations must accomplish these goals in order to be successful (see Ariew et al. 2015; Batterman and Rice 2014; Huneman 2010; Morrison 2015; Pincock 2012, 2018; Rice 2012, 2015, 2017 or Sober 1983 for some examples). Instead of requiring the use of multiple models to satisfy all of these criteria before we can claim that an explanation has been provided, we have argued that in different cases different subsets of features will be sufficient to provide an explanation.

These differences between our view and Hochstein's also have important implications for how we ought to evaluate the explanatory successes of science. Given that in many cases we will lack models that can satisfy some of the explanatory goals on Hochstein's list—e.g. in many

[24] We actually think that Hochstein is committed to a kind of monism in that he argues that all explanations must satisfy the same criteria despite arguing that no *single* goal is most important. In other words, Hochstein seems to reject the explanatory pluralism that we aim to account for that claims that there are multiple different kinds of explanation provided in science.

cases, no mechanistic model exists for a complex phenomenon—Hochstein's view implies that science has provided far fewer explanations than scientists have claimed. In contrast, our view has focused on the plurality of ways that scientists explain phenomena and shows how, despite that plurality, each of those explanations can be shown to be sufficient and valuable in their own right. Thus, rather than suggesting, as Hochstein (2017) does, that science cannot explain without simultaneously conveying understanding, showing the phenomenon was expected, identifying general principles, identifying physical mechanisms, and enabling manipulation and control, we contend that the diverse range of explanations surveyed above shows that scientists have successfully explained in many different ways despite failing to satisfy many of the criteria of explanations in any particular case. This is precisely why a cluster concept is required: without it we are back to suggesting that a certain set of features are necessary and sufficient for all explanations in ways that fail to do justice to the plurality of ways that scientists explain.

6. Conclusion

We have argued that we can resurrect the goal of attempting to provide a unified account of explanation by reconceiving of explanation as a cluster concept. In order to motivate this claim, we have argued that, while there are multiple overlapping sufficient subsets of features, no single feature is necessary for all explanations. On the one hand, any features that are common to all explanations will be too uninformative to provide a normative account of how explanations ought to be provided and why explanations are epistemically valuable. On the other hand, any set of conditions that are sufficient to normatively guide the construction of explanations and account for explanations' epistemic value will not be necessary for all explanations. Abandoning the search for necessary conditions for all explanations and reconceiving of explanation as a cluster concept enables us to move beyond the never-ending cycle of proposing universal accounts and counterexamples to those accounts. Consequently, our analysis implies that instead of using counterexamples to demonstrate that certain features are not necessary for explanations, philosophers need to investigate whether particular subsets of features are genuinely sufficient for providing an explanation. In addition, we have argued that conceiving of explanation as a cluster concept enables us to account for the widespread disagreement observed in the philosophical literature on explanation. Moreover, we have shown that a cluster concept approach to explanation can avoid the dilemma Pincock raises for explanatory pluralism by maintaining a unified concept of explanation while still recognizing the myriad ways scientists provide explanations. If these arguments are successful concerning the concept of explanation, then a cluster concept approach might be useful in other philosophical debates where a similar tension arises between the hope of discovering a universal account of concept X and recognizing the diversity of ways that concept X is used. That is, perhaps additional philosophical debates can benefit from less of a focus on identifying necessary conditions for all applications of a concept.

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