EXPLANATORY UNIFICATION AND SCIENTIFIC UNDERSTANDING

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1. Introduction

This paper represents a response to the criticisms made by Eric Barnes in "Explanatory Unification and the Problem of Asymmetry" and "Explanatory Unification and Scientific Understanding" against the thesis of Explanatory Unification.[1] This paper responds to Barnes' two main criticisms, that of derivational skepticism and causal asymmetry, and successfully refutes his objections. This paper also defends the plausibility of the unificationist account of scientific explanation because of its ability to render coherent the notion of scientific understanding. In doing so, this paper focuses on Michael Friedman's account of Explanatory Unification. This is chosen because of his extensive treatment of scientific understanding. Other (perhaps technically more sound) accounts of unification, especially Philip Kitcher's detailed formulation, will also be utilized in responding to Barnes' objections.[2]

I begin in Section Two with a positive defense of Explanatory Unification, elucidating Friedman's account of unification, paying particular attention to the notion of scientific understanding. In Sections Three and Four, I defend Explanatory Unification against the charges of Barnes on the issues of derivational skepticism and causal asymmetry. In doing so, I aim to clarify the basic motivations of the Explanatory Unificationist. The final section, Section Five, presents some additional issues relevant to scientific explanation. I conclude that until these other questions are resolved, an ultimate evaluation of the success of Explanatory Unification as a comprehensive theory of explanation cannot be made. However, although Explanatory Unification is susceptible to

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[1] E. Barnes, *Explanatory Unification and the Problem of Asymmetry*, (EUPA hereafter) «Philosophy of Science», 59 (1992), pp. 558-571 and E. Barnes, *Explanatory Unification and Scientific Understanding*, (EUSU hereafter), *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, 1 (1992), pp. 3-12.

[2] For some recent alternative defenses of Explanatory Unification see: G. Schurz, *Explanation as Unification*, «Synthese», 120 (1999), pp. 95-114; and R. Schweder, *A Defense of a Unificationist Theory of Explanation*, «Foundations of Science», 10 (2005), pp. 421-435.

certain difficulties, it *does* answer the objections of derivational skepticism and causal asymmetry, and thus we should continue to search for better formulations of the unificationist approach to scientific explanation.

2. Scientific Understanding and Friedman's Explanatory Unification

Wesley Salmon maintains that the purpose of science is not just to describe the world, but also to provide understanding, comprehension, and enlightenment. Furthermore, science provides these things through scientific explanations. Thus, scientific explanation is fundamentally tied to understanding of some sort. Given this, Salmon believes the questions to which we should be seeking answers are: «If explanation does involve something over and above mere description, just what sort of thing is it?» and «What, over and above descriptive knowledge of the world, is required in order to achieve understanding?».[3]

It is appropriate, then, that central to Michael Friedman's Explanatory Unification doctrine is the notion of 'scientific understanding'. For Friedman also believes the principal problem for any theory of scientific explanation is the following: «What is the relation between phenomena in virtue of which one phenomenon can constitute an explanation of another, and what is it about this relation that gives understanding of the explained phenomenon?"[4] Resolving this dilemma, however, also requires discovering what it is for a phenomenon to be 'scientifically understandable'. And, according to Friedman, "We can find out what scientific understanding consists in only by finding out what scientific explanation is and vice versa».[5] He further asserts that the concept of scientific understanding is vague, but that what is explained is a general regularity or pattern of behavior (a law) and a regularity is explained by relating (reducing) it to another regularity.

Friedman's project, then, is to provide accounts of traditional theories of explanation and show how they are insufficient to account for understanding. He also outlines the general properties that the concept of scientific understanding should have, and he proposes an account of scientific explanation that possesses these desirable properties. In addition, Friedman discriminates among two primary groups of scientific explanation. The first group represents the traditional received view and includes Hempel and Nagel. The second group consists in the causal/mechanistic/pragmatic approaches and includes Scriven, Toulmin, and Dray. Friedman claims that neither of these

[3] W. Salmon, *Scientific Explanation and the Causal Structure of the World*, Princeton UP, Princeton 1984, p. 9.

[4] M. Friedman, *Explanation and Scientific Understanding*, «Journal of Philosophy», 71 (1974), pp. 5-19, p. 6.

[5] *Ibidem*.

groups sufficiently explain both scientific explanation and scientific understanding:

«Some philosophers, like Hempel and Nagel, have relatively precise proposals as to the nature of the explanation relation, but relatively little to say about the connection between their proposals and scientific understanding, i.e., about what it is about the relation they propose that gives us understanding of the world. Other philosophers, like Toulmin, Scriven, and Dray, have a lot to say about understanding, but relatively vague ideas about just what relation it is that produces this understanding».[6]

Philip Kitcher agrees with Friedman that the nature of scientific explanation should include understanding: «A theory of explanation should show us *how* scientific explanation advances our understanding».[7] Moreover, Kitcher claims that scientific understanding is closely tied to unification:

«My view of explanation as unification suggests how scientific explanation yields understanding. By using a few patterns of argument in the derivation of many beliefs we minimize the number of types of premises we must take as underived. That is, we reduce, in so far as possible, the number of types of facts we must accept as brute. Hence we can endorse something close to Friedman's view of the merits of explanatory unification».[8]

Many, however, disagree with Friedman's thesis that scientific understanding is important to scientific explanation.[9] For Carl Hempel, scientific explanation is not intimately tied with scientific understanding. Hempel declares that, «such expressions as 'realm of understanding' and 'comprehensible' do not belong to the vocabulary of logic, for they refer to the psychological or pragmatic aspects of explanation».[10] Furthermore, «explanation in this pragmatic

[6] *Ibidem*.

[7] P. Kitcher, *Explanatory Unification*, «Philosophy of Science», 48 (1981), pp. 507-531, p. 508. See H. de Regt and D. Dieks, *A Contextual Approach to Scientific Understanding*, «Synthese», 144 (2005), pp. 137-170 for a nice discussion of the notion of scientific understanding as it finds expression in different theories of scientific explanation.

[8] P. Kitcher, *Explanatory Unification*, cit., pp. 529-530.

[9] Bas van Fraassen, for instance, is opposed to the claim there is a necessary connection between scientific explanation and understanding. «The real focus of disagreement may be the relation between explanation and understanding. …All I have to say here is that our understanding can sometimes be increased otherwise than by receiving explanation and that we may sometimes be in a position (in view of our interests, background information, and beliefs) to receive an explanation of one case and not of another even though the total scientific information, by itself, harbors no such asymmetry» (B. van Fraassen, *Salmon on Explanation*, «Journal of Philosophy», 82 (1985), pp. 639-651, p. 642).

[10] C. Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science*, Free Press, New York 1965, p. 413. Hempel is very clear in distinguishing scientific understanding from psychological or empathic understanding: «It is important to distinguish here understanding in the psychological sense of feeling of empathic familiarity from un-

sense is thus a relative notion: something can be significantly said to constitute an explanation in this sense only for this or that individual».[11]

Hempel, instead, provides an account of scientific explanation that regards understanding as predictive power. He says, «the [D-N] argument shows that, given the particular circumstances and the laws in question, the occurrence of the phenomenon *was to be expected*; and it is in this sense that the explanation enables us to *understand why* the phenomenon occurred».[12] However, according to Friedman, Hempel's claim amounts to the idea that knowing "the particular circumstances and laws in question" is just to have "rational grounds" for expecting the explained phenomenon to occur. But, to have grounds for rationally expecting some phenomenon is not the same as to understand it.[13] For example, a barometer may provide rational grounds for expecting a storm to occur. But, most agree a barometer does not help us to understand *why* the storm is about to occur. Rather, more information is necessary to provide *understanding* of the occurrence of the storm.

Friedman is willing to concede that the D-N model has the many advantages. For example, the D-N model provides entailment, which is a necessary condition for explanation. Furthermore, it retains the objective character of explanation, not depending on the arbitrary attitudes of the scientist or the historical period. However, Friedman reminds us, the D-N model must ultimately be replaced because it has not succeeded in saying what it is about the explanation relation that provides understanding of the world. Any adequate theory of explanation must somehow connect explanation and understanding, and the D-N model is deficient in this respect.

Another issue central to scientific understanding and explanation is the notion of 'familiarity'. Hempel rejects the idea that scientific explanation resides in a reduction of phenomena to things familiar: «the frequent insistence that explanation means the reduction of something unfamiliar to ideas or experiences already familiar to us is indeed misleading. For while some scientific explanations do have this psychological effect, it is by no means universal».[14]

derstanding in the theoretical, or cognitive, sense of exhibiting the phenomenon to be explained as a special case of some general regularity» (*ibidem*, pp. 256-67). See also J. Trout, *Scientific Explanation and the Sense of Understanding*, «Philosophy of Science», 69 (2002), pp. 212-233, and *The Psychology of Scientific Explanation*, «Philosophy Compass», 2 (2007), pp. 564-591.

[11] C. Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science*, cit., p. 426. [12] *Ibidem*, p. 337. [13] M. Friedman, o.c., p. 8.

[14] C. Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science*, cit., p. 257. See also p. 329. On the other side, however, there are those, such as Michael Scriven and Gerard Schurz, who argue that an explanation of something unfamiliar in terms of something else *un*familiar does not constitute a sufficient explanation. For example, Bohr's stability postulates for electrons in an atom were able to successfully predict the hydrogen

In spite of their disagreement over the importance of understanding for explanation, Friedman agrees with Hempel that understanding does not reside in familiarity, and thus, familiarity is not essential to explanation. «For, being familiar, just like being expected, is not at all the same thing as being understood. We are all familiar with the behavior of household appliances… but how many of us understand why they behave the way they do?»[15] In rejecting the claim that scientific explanation must reduce phenomena to the familiar, Friedman argues that there are many cases of genuine scientific explanation whose explanans are more unfamiliar than the explanandum. For example, science explains the refraction of light, something familiar, by appealing to electromagnetic waves, something relatively unfamiliar. Friedman further supports his case by pointing out that if explanations had to reduce phenomena to the familiar, most of the explanations offered by contemporary physics could not possibly explain.

However, Friedman concedes that in many of these scientific explanations, no gain in understanding is produced. For instance, in the paradigm case of using the kinetic theory to explain the Boyle-Charles law of gases, this scientific explanation does not amount to a gain in understanding since it "merely replaces one brute fact with another." But, this concession does not rule out the necessity of understanding for explanation, according to Friedman. Rather, this allows Friedman to formulate a distinction between 'local' and 'global' understanding. In other words, Friedman believes that scientific explanation involves an increase in global understanding even if, locally, one unfamiliar fact is replaced with another.[16] Thus, Friedman's position relies upon a subtle distinction between types of understanding. The idea here is that accounts of scientific explanation that require reducing unfamiliar phenomena to familiar

spectrum, but because they were inconsistent with classical mechanics, they were themselves in need of explanation. Thus, most scientists did not believe Bohr's postulates could be an explanation for atomic behavior. Hence, even if the unfamiliar phenomena are able to successfully predict, and even causally explain, the explanandum, they cannot provide explanation. According to Scriven, explanation is fundamentally tied to both familiarity and understanding, because *understanding resides in familiarity* (M. Scriven, *Truisms as the Grounds for Historical Explanation*, in P. Gardiner (ed.), *Theories of History*, Free Press, Glencoe 1959). Moreover, Schurz believes there is a semantic connection between scientific explanation and scientific understanding directly related to familiarity. His position asserts that something *cannot* be an adequate explanation even if what does the explaining is not itself completely understood or familiar. «[There is a] widespread view that explanation and understanding are semantically related in the sense that an explanation (of P) is satisfying iff it provides understanding (of P). For it is reasonable to argue that one cannot *understand something* (P) by means of some other thing (Prem) which one *has not understood*» (G. Schurz, o.c., pp. 97-98).

[15] M. Friedman, o.c., p. 10.

[16] See also L. Fahrbach, *Understanding Brute Facts*, «Synthese», 145 (2005), pp. 449-466.

ones are inadequate because they require a special epistemological status on the part of the phenomenon doing the explaining. This is unacceptable, according to Friedman, because often the phenomena doing the explaining are themselves brute facts. This type of explanation equates 'understanding' with 'familiarity'. Friedman, however, wishes to retain the notion of 'understanding' as a necessary condition for explanation, but does not believe understanding resides in familiarity.

Moreover, 'mere gain of information' is also an inadequate account of understanding because a gain of information does not mean a gain of understanding. Thus, while the explanation of the Boyle-Charles law of gases by kinetic theory is a genuine explanation, it is *not* because it produces a gain of understanding through a gain of information, but instead, because understanding is produced on the global level.[17] Understanding, rather, resides in reducing the total number of independent phenomena that we have to accept as ultimate or given. Friedman states:

«On the view of explanation that I am proposing, this kind of understanding provided by science is global rather than local. Scientific explanations do not confer intelligibility on individual phenomena by showing them to be somehow natural, necessary, familiar, or inevitable. However, our over-all understanding of the world is increased; our total picture of nature is simplified via a reduction in the number of independent phenomena that we have to accept as ultimate. …[P]revious attempts…have failed through ignoring the global nature of scientific understanding. If one concentrates only on the local aspects of explanation – the phenomenon being explained, the phenomenon doing the explaining, and the relation (deductive or otherwise) between them – one ends up trying to find some special epistemological status – familiarity, naturalness, or being an 'ideal of natural order' – for the phenomenon doing the explaining. … [A]ttention to the global aspects of explanation…allows one to dispense with any special epistemological status for the phenomenon doing the explaining. As long as a reduction in the total number of independent phenomena is achieved, the

[17] Immediately one might interject here and object to the idea that global understanding is related to scientific explanation. Bas van Fraassen, for example, objects that Friedman's view of unification «totally discount[s] a specific relation of explanation altogether» (B. VAN FRAASSEN, *The Scientific Image*, Clarendon, Oxford 1980, p. 109). In other words, explanation is a local affair and thus requires local understanding. Schurz sidesteps this objection by combining Friedman's global account with a local component. His theory of Explanatory Unification takes the following form: (E) A is an *explanatory satisfying answer* to the question Why-P? in the cognitive state C iff (i) A claims (for some Prem) Prem & Prem → P, where Prem → P is a premise-relevant correct inference in a broad sense, and (ii) C + A > $_u$ C," where 'C' is the cognitive state of the questioner; 'Why-P?' is the explanation-seeking question and 'P' is in need of explanation; 'A' is the answer; 'Prem' are premises; and '> $_u$' is the well-defined partial order relation between the cognitive states (of cognitive agents or systems) measuring their degree of unification. Condition (i) is local and condition (ii) is global, though dependent upon the local condition (i) (G. SCHURZ, o.c., pp. 98-99).

basic phenomena to which all others are reduced can be as strange, unfamiliar, and unnatural as you wish – even as strange as the basic facts of quantum mechanics».[18]

Thus, Friedman's motivation in rejecting this account and the previous ones is that they all require the phenomenon doing the explaining to have some sort of special epistemological status.[19] But many of our explanans are brute facts. The elementary particles of physics and their behavior, for example, are brute facts that are not themselves understood, but are still able to explain other phenomena.

The question this raises, however, is how something not understood can provide an "intelligibility transfer" to another phenomena to produce understanding. In other words, many standard accounts of scientific explanation, including the ones most recently mentioned, believe that «the intelligible quality of the explanans flows down the argument, as it were, across the line dividing explanans and explanandum, and into the explanandum, displacing the latter's mysterious quality».[20] Friedman's answer to the above question is simply that there is no such "intelligibility transfer." Furthermore, "to derive a fact from any premises whatsoever…is never by itself sufficient to render that fact as less mysterious than it was before, because the premises are inevitably ultimately mysterious».[21] Barnes refers to this as Friedman's «Thesis of Derivational Skepticism." This anticipates the problem of deductive explanations of laws, the discussion of which will be postponed until the next section.

Given all of the above considerations, how are we now to evaluate the relation of explanation to understanding, if it is not a matter of familiarity or intelligibility transfer, according to Friedman? What does understanding consist of? Friedman's answer is that «science increases our understanding of the world by reducing the total number of independent phenomena that we have to accept as ultimate or given. A world with fewer independent phenomena

[18] M. Friedman, o.c., p. 18.

[19] In line with this, Friedman also criticizes what he calls the "intellectual fashion view." According to this position, «the meaning of 'scientific understanding' varies with historical tradition, since what counts as an ideal of intelligibility does. Consequently, the very same theory may count as explanatory for one tradition but may fail to explain for another. … most believe that there can be good reasons, usually having to do with predictive power, for choosing one ideal over another. Indeed, one writer, N.R. Hanson, practically identifies predictive power with intelligibility». But, Friedman argues, «it would be desirable to find a concept of explanation according to which what counts as an explanation does not depend on what phenomena one finds particularly natural or self-explanatory. In fact, although there may be good reasons for picking one 'ideal of natural order' over another, I cannot see any reason but prejudice for regarding some phenomena as somehow more natural, intelligible, or self-explanatory than others. All phenomena…are equally in need of explanation – although it is impossible, of course, that they all be explained at once» (M. Friedman, o.c., pp. 12-13).

[20] E. Barnes (eusu), o.c., p. 4.

[21] *Ibidem*.

is, other things equal, more comprehensible than one with more».[22] Furthermore, it is not simply replacing one puzzling phenomenon with another, but replacing one phenomenon with a more comprehensive phenomenon, and thereby effecting a reduction in the total number of accepted phenomena. A phenomenon's being itself unexplained does not prevent it from explaining other phenomena.

To demonstrate this, Friedman introduces the notion of independently acceptable law-like sentences. A law-like sentence is independently acceptable if «there are sufficient grounds for accepting one which are not also sufficient grounds for accepting the other». It also satisfies the following two conditions:

1) If $S \vdash Q$ then S is not acceptable independently of Q.

2) If S is acceptable independently of P and $Q \vdash P$, then S is acceptable independently of Q.

Friedman supposes that there is at any given time a set K of law-like sentences that are accepted by the scientific community. A sentence is then K-atomic if it has no partition: "if there is no pair $\{S_1, S_2\}$ such that S_1 and S_2 are acceptable independently of S and S_1 & S_2 is logically equivalent to S." Friedman then defines scientific explanation using this terminology. He explains that if S is to explain some S′ in K, then the set that S must reduce is the set of independently acceptable consequences of S ($con_K(S)$). Thus, Friedman's definition of scientific explanation is:

(D1′) S_1 explains S_2 iff there exists a partition Γ of S_1 and an $S_i \in \Gamma$ such that $S_2 \in con_K(S_i)$ and S_i reduces $con_K(S_i)$.[23]

Friedman's archetypal example of a case of scientific unification is the subsumption of several laws under the laws of mechanics. He states:

«Consider a typical scientific theory – e.g., the kinetic theory of gases. This theory explains phenomena involving the behavior of gases, such as the fact that gases approximately obey the Boyle-Charles law, by reference to the behavior of the molecules of which gases are composed. For example, we can deduce that any collection of molecules of the sort that gases are, which obeys the laws of mechanics will also approximately obey the Boyle-Charles law. How does this make us understand the behavior of gases? I submit that if this were all the kinetic theory did we would have added nothing to our understanding. We would have simply replaced one brute fact with another. But this is not all the kinetic theory does – it also permits us to derive other phenomena involving the behavior of gases, such as the fact that they obey Graham's law of diffusion and (within certain limits) that they have the specific-heat capacities that they do have, from the same laws of mechanics. The kinetic theory effects a significant unification in what we have to accept. Where we once had three independent brute facts – that gases approximately obey the Boyle-Charles law, that

[22] M. Friedman, o.c., p. 15. [23] *Ibidem*, pp. 16-17.

they obey Graham's law, and that they have the specific-heat capacities they do have – we now have only one – that molecules obey the laws of mechanics. Furthermore, the kinetic theory also allows us to integrate the behavior of gases with other phenomena, such as the motions of the planets and of falling bodies near the earth. This is because the laws of mechanics also permit us to derive both the fact that planets obey Kepler's laws and the fact that falling bodies obey Galileo's laws. From the fact that all bodies obey the laws of mechanics it follows that the planets behave as they do, falling bodies behave as they do, and gases behave as they do. Once again, we have reduced a multiplicity of unexplained, independent phenomena to one. I claim that this is the crucial property of scientific explanation – science increases our understanding of the world by reducing the total number of independent phenomena that we have to accept as ultimate or given. A world with fewer independent phenomena is, other things equal, more comprehensible than one with more».[24]

However, there have been two chief objections raised against the technical formulations of Friedman's account. The first is that Friedman's account only allows K-atomic sentences to explain. The second objection is that under Friedman's account there are no K-atomic sentences. If these two objections hold weight, then Friedman's account of explanation does no explaining, or as Salmon says, it «cannot get off the ground».[25]

In regard to the first objection, Friedman's definition of explanation implies that only K-atomic sentences can explain, which is clearly not the case. Kitcher provides two types of counterexamples to demonstrate that Friedman's definition is too restrictive. One is when we explain the behavior of a complex system by using laws from different theories and the other is when we have independently acceptable laws which belong to the same theory and can be put together in genuine explanations. His example for the second type of counterexample is the usual derivation of the law of adiabatic expansion of an ideal gas. The explanans is the conjunction of the Boyle-Charles law and the first law of thermodynamics. But, because these laws are acceptable on the basis of quite independent tests, their conjunction is not K-atomic. However, Kitcher argues, the derivation of the law of adiabatic expansion from the conjunction is a genuine explanation. Kitcher also argues that Friedman's example of the explanation of the Boyle-Charles law by the kinetic theory is not K-atomic. Briefly, the second criticism comes out of Friedman's attempt to accommodate this first criticism by revising his definition of explanation. Kitcher argues that it now entails that no K-atomic sentence can explain anything. The main weakness Kitcher sees in Friedman's account of Explanatory Unification is Friedman's failure to provide a technically sound account of unification:

[24] *Ibidem*, pp. 14-15.

[25] W. Salmon, *Four Decades of Scientific Explanation*, University of Minnesota Press, Minneapolis 1989, p. 99.

«Consider the intuitive method of counting laws which we normally employ and according to which the conjunction of Newton's laws would be regarded as three laws. If we look at the class of explanations that use the principles of Newtonian mechanics we find that, by our intuitive count, the number of laws invoked in explanantia is not significantly less than the number of laws derived as explananda. What is much more striking than the relation between these numbers is the fact that Newton's laws of motion are used again and again and that they are always supplemented by laws of the same types, to wit, laws specifying force distributions, mass distributions, initial velocity distributions, etc. Hence the unification achieved by Newtonian theory seems to consist not in the replacement of a large number of independent laws by a smaller number, but in the repeated use of a small number of types of law which relate a large class of apparently diverse phenomena to a few fundamental magnitudes and properties. Each explanation embodies a similar pattern: from the laws governing the fundamental magnitudes and properties together with laws that specify those magnitudes and properties for a class of systems, we derive the laws that apply to systems of that class».[26]

Consequently, Kitcher wishes to retain the connection between unification and explanation, but believes he can provide a more technically sound approach. His account, instead, relies upon derivational patterns for the unification of scientific explanation. Kitcher's formulation does much to ameliorate Friedman's difficulties, and the difficulties in Friedman's formulation of K-atomicity are not carried over into Kitcher's unificationist view. However, there are other objections Friedman and Kitcher must face if their unification accounts are to stand up as plausible theories of scientific explanation. I will focus on two criticisms leveled by Eric Barnes: (1) Explanatory Unification is internally inconsistent and fails to provide an adequate account of understanding, and (2) Explanatory Unification cannot account for causal asymmetries. The next section will address the first criticism.

3. Explanatory Unification and Derivational Skepticism

Barnes argues that Explanatory Unification is inconsistent and thus, cannot adequately account for scientific understanding. Moreover, Barnes believes he can successfully replace Explanatory Unification (which he thinks has become futile) with a causal account of understanding. Given Friedman's commitment to the importance of scientific understanding, this is a substantial worry for the overall cogency of Explanatory Unification, if these objections are successful. In formulating his objection, Barnes charges Friedman with having the very same problems that Friedman accuses competing theories of

[26] P. Kitcher, *Explanation, Conjunction, and Unification*, «Journal of Philosophy», 73 (1976), pp. 207-212, pp. 209-10.

having. Essentially, Barnes argues that Friedman's view is no less derivational than the traditional deductive models.

To demonstrate this, Barnes elucidates what he believes is Friedman's main criticism of competing theories. He refers to this as the "Thesis of Derivational Skepticism." The idea here is that Friedman rejects competing theories on the basis of the idea that derivation does not equal understanding. Scientific understanding cannot be produced merely by the derivation of an explanandum from some explanans. Moreover, Barnes claims that Friedman attacks the traditional views on the basis that these views are mistaken in thinking that the "mysterious quality" of explananda is understood in deriving them from some suitable explanans. Next, Barnes argues that the premises that led Friedman to his Derivational Skepticism are the same ones he relies upon in formulating his thesis of Explanatory Unification – Friedman's view utilizes the very same deductive principles. This is because he characterizes Friedman's thesis of Explanatory Unification as follows: «We understand the world better when we countenance fewer independent phenomena because the presence of fewer independent phenomena in our picture of nature amounts to the presence of fewer fundamental mysteries. The fewer fundamental mysteries we are forced to accept, the less mystified we are: the better we understand the world. QED».[27]

Barnes then illuminates the supposed inconsistency by claiming that the plausibility of the Unificationist Thesis of Understanding is dependent entirely upon the premise that an underived, independent phenomenon represents a mystery not represented by a derived, dependent phenomenon. Barnes states:

«To derive a fact from any premises whatsoever, Friedman is suggesting, is never *by itself* sufficient to render the fact as less mysterious than it was before, because the premises are inevitably ultimately mysterious. If the premises are themselves derivable from some deeper theory T, this theory will either be mysterious (in the sense that its truth is unexplained) or derivable from some still deeper theory…. Hence, from Friedman's viewpoint, it is entirely unclear how understanding of any explanandum is (or will ever be) possible at all. …It seems to me, in other words, that the Unificationist Thesis of Understanding ought to be considered as plausible only if we antecedently assume some account of understanding according to which individual explananda are rendered understood, in some sense, by means of their standing under a suitable explanans. But the falsehood of any such account was the punchline of the Thesis of Derivational Skepticism, which is in turn supposed to be one of the most crucial motivations for adopting the Unificationist Thesis of Understanding. If we are to reject, with Friedman and Kitcher, the local nature of explanation and understanding on the grounds of the Thesis of Derivational Skepticism, the

[27] E. Barnes (eusu), o.c., p. 6.

question why we should take understanding to be proportional to the unified status of our global theoretical picture emerges as a very pressing one».[28]

However, as formulated, this objection appears to miss the point. Friedman is quite willing to countenance genuine explanations that involve unfamiliar or mysterious explanans. Perhaps, Barnes' point is that Friedman's notion of global unification presupposes a notion of local explanation. That is, global unification is a matter of a few brute premises being able to locally explain lots of independently acceptable laws. Even so, I think that Friedman can fend off this objection.[29] Moreover, Barnes claims that Friedman's account fails to provide an adequate account of event explanation. Instead, Barnes argues that Salmon's causal mechanistic account can successfully resolve Friedman's problems. Yet, this objection appears to be misguided as well. First, it is the case that Friedman attacks certain derivational accounts of explanation, but these are accounts that deal with deriving *laws* from other *laws*. But, Barnes' attack is based on the derivation of events, which does not appear to be the motivation for Friedman's adoption of the thesis of Explanatory Unification. Rather, it is more plausible to assert that Friedman's actual motivation is to resolve Hempel and Oppenheim's difficulty with explaining general laws by the D-N model. This is further supported by Salmon's statement that Friedman restricted the applicability of unification to regularities.[30]

Thus, the real problem Explanatory Unification must face is the ability to explain laws by other laws without trivial deductions of general regularities.[31] In other words, Friedman's account must be able to rule out, for example, the derivation of a law from a conjunction of itself and another unrelated law as a case of genuine explanation. This offers no explanation or understanding because the conjunction of these two laws does not reduce its "independently acceptable consequences." Hempel and Oppenheim present the problem of explaining general regularities in a famous footnote:

[28] *Ibidem*, pp. 4, 6.

[29] See also L. Fahrbach, o.c., pp. 460-464, in which he defends Friedman against Barnes by emphasizing that many brute facts increase our global scientific understanding.

[30] W. Salmon, *Four Decades of Scientific Explanation*, cit., p. 184.

[31] William Kneale, who offers his own account of unification, provides an example of the problem of explaining laws: "When we explain a given proposition we show that it follows logically from some other proposition or propositions. But this can scarcely be a complete account of the matter. For if I hear that there is a lion in my garden and demand an explanation of this curious fact, I am certainly not satisfied by a statement that there are two lions in my garden, although the first proposition follows logically from the second. An explanation must in some sense simplify what we have to accept. Now the explanation of laws by showing that they follow from other laws is a simplification of what we have to accept because it reduces the number of untransparent necessitations we need to assume, but this may not be obvious at first sight" (W. Kneale, *Probability and Induction*, Clarendon, Oxford 1952, p. 91).

«The precise rational reconstruction of explanation as applied to general regularities presents peculiar problems for which we can offer no solution at present. The core of the difficulty can be indicated by reference to an example: Kepler's laws, K, may be conjoined with Boyle's law, B, to [form] a stronger law K.B; but derivation of K from the latter would not be considered an explanation of the regularities stated in Kepler's laws; rather, it would be viewed as representing, in effect, a pointless "explanation" of Kepler's laws by themselves. The derivation of Kepler's laws from Newton's laws of motion and gravitation, on the other hand, would be recognized as a genuine explanation in terms of more comprehensive regularities, or so-called higher-level laws. The problem therefore arises of setting up clear-cut criteria for the distinction of levels of explanation or for a comparison of generalized sentences as to their comprehensiveness. The establishment of adequate criteria for this purpose is as yet an open problem».[32]

Salmon argues that if Friedman can resolve the problems of K-atomic sentences, then his account of explanation will solve Hempel and Oppenheim's problem.[33]

Barnes' objection to Friedman, then, must be that *only* a causal account of explanation can solve this problem. This, however, has yet to be demonstrated and now the burden of proof is on Barnes' side. Barnes believes that he can replace Explanatory Unification and global understanding by explaining particular facts through their causal basis. Even if this is the case, however, this provides no compelling reason to reject the thesis of Explanatory Unification altogether. This can be seen by examining Salmon's views on the compatibility of unification theories with causal mechanistic theories.

Salmon claims that the unification view (top-down) is compatible with a causal or mechanistic view (bottom-up). Neither of these views need be rejected, but can rather be seen as two different ways of utilizing the ideal explanatory text (the causal view being primarily used for events and the unification view being used primarily for laws). As an illustration, he offers a scenario where a physicist is asked to explain the motion of a balloon in an airplane. Salmon explains that this explanation can be given on either a global or local level. That is, the physicist can either provide a causal mechanistic explanation involving the behavior of molecules or he can provide a unification explanation by citing Einstein's principle of equivalence and showing how the motion of the balloon fits under this general law. Neither of these explanations is incorrect, and which one to utilize is only a matter of context.[34]

[32] C. Hempel - P. Oppenheim, *Studies in the Logic of Explanation*, «Philosophy of Science», 15 (1948), pp. 135-175, p. 159, n. 28.

[33] W. Salmon, *Four Decades of Scientific Explanation*, cit., p. 100.

[34] *Ibidem*, pp. 183-85. And, how distinct these explanations really are depends on the relation between causation and the equivalence principle. See also W. Salmon, *Scientific Expla-*

This insight by Salmon raises the question over whether Explanatory Unification is a genuine rival to the causal approach. Moreover, what exactly is the relation between unification and causality? Most importantly, can the demand for causal reasons be solely explained in terms of unification increase? Kitcher, however, particularly in his 1989 work, does seem to advocate the exclusive acceptance of Explanatory Unification over the causal approach, because the explanatory powers of causal reasons can be solely explained by unification. Kitcher argues that causal claims should be grounded in explanatory dependency. Causal dependence is derivative of explanatory dependence. For Kitcher, then, Explanatory Unification is not set up as a complement to the causal approach, unification being used for laws and causality being used for events. Rather, Explanatory Unification can explain both laws and events by an appeal to the explanatory store.[35] In order to do this however, Kitcher needs to be able to account for our intuitive understanding of causal asymmetry. If Kitcher is able to demonstrate this, then Explanatory Unification should be evaluated on its merits alone without conceding any lack of ability to explain events. Gerhard Schurz, to the contrary, believes that unification cannot explain causal reasons of singular events, but that it can provide causal explanations of laws. His reasoning for this is also based on the consideration of causal asymmetry and his contention that unification cannot adequately account for it. In view of this, I will now turn to an examination of the problem of causal asymmetry, with an eye to whether Explanatory Unification is a view that can stand on its own, particularly with respect to the explanation of particular events.

4. Explanatory Unification and Asymmetry

It is commonly recognized in the famous tower-shadow example that the height of tower *is* a genuine explanation for the length of the shadow, whereas the length of the shadow *is not* a genuine explanation for the height of the tower.[36] However, this example presents several problems for the traditional

nation: Causation and Unification, in *Causality and Explanation*, Oxford UP, Oxford 1998. For an opposing view, see E. Weber and J. van Bouwel, *Causation, Unification, and the Adequacy of Explanations of Facts*, «Theoria», 24 (2009), pp. 301-320.

[35] P. Kitcher, *Explanatory Unification and Causal Structure*, in «Minnesota Studies in the Philosophy of Science», Volume xi: *Scientific Explanation*, U of Minnesota Press, Minneapolis 1989, p. 436.

[36] This example was provided by B. van Fraassen, *The Scientific Image*, cit., pp. 132-134, and seems to be derived from Bromberger's flagpole-shadow example in *A Theory about the Theory of Theory and about the Theory of Theories* in B. Baumrin (ed.), *Philosophy of Science: The Delaware Seminar,* Vol. 2, Wiley & Sons, New York 1963; and *Why Questions*, in R. G. Colodny (ed.), *Mind and Cosmos: Essays in Contemporary Science and Philosophy,* University of Pittsburgh P, Pittsburgh 1966. See W. Salmon, *Four Decades of Scientific Explanation*, cit., p. 47 for treatment of the flagpole-shadow example.

D-N model. In addition to issues of temporal asymmetry there are also issues of causal asymmetries. The reason we do not want to explain the tower height in terms of the shadow's length is because of our belief that effects do not explain their causes. However, according to the D-N model, both directions are equally explanatory because of inferential symmetry. Built into the D-N model is the symmetry of explanation and prediction. The same logical schema is applied both to explanation and prediction so that nomically connected temporally later events including effects can serve in genuine explanations. Because this is counterintuitive, modifications of the D-N model must be made to accommodate such asymmetries. Explanation cannot merely consist in deductive derivation.[37]

Barnes charges Explanatory Unification with being unable to explain why one is a genuine explanation and not the other. In other words, under Explanatory Unification, derivations moving in both directions would count as explanations, much like the D-N model. Thus, Explanatory Unification cannot accommodate the causally asymmetric nature of explanation.[38] Because the issue of asymmetry is explicitly addressed in Kitcher and not by Friedman, I will utilize Kitcher's formulation of Explanatory Unification when defending it against the charge of being unable to account for causal asymmetry. Barnes charges Kitcher's account with having two equally unifying argument patterns in the tower-shadow case. Barnes argues that both the origin and development (O&D) pattern of length explanation and the shadow-based explanation (SBE) pattern have an equally unifying effect, and thus, equally unifying explanatory stores. Schurz agrees with Barnes and explains that for individual events, utilizing the unification approach fails to capture the causal direction:

«Concerning the explanation of singular events, considering a biconditional law A↔B where only the direction from A to B is the causal one. Why should it be more unifying to explain B-events by A-events than to explain A-events by B-events? A detailed analysis shows that if the law is deterministic, the situation is completely equivalent vis-à-vis unification, since every third event C must be correlated with A and with B to exactly the same probabilistic degree. Thus, in the area of explana-

[37] W. SALMON, *Four Decades of Scientific Explanation*, cit., pp. 46-50.

[38] Barnes cites Kitcher's antirealist stance toward causation due to Humean worries and then wonders how explanatory stories can account for the causal structure of the world. He says, "Kitcher thus takes his theory of explanation to do what causal theories cannot do: establish the very possibility of understanding the causal structure of the world (despite the Humean predicament), and thus establish the very possibility of possessing knowledge with explanatory force." Barnes is thus quite skeptical that Kitcher's project can be carried out (E. Barnes (EUPA), o.c., p. 560). See also V. GIJSBERS, *Why Unification is Neither Necessary nor Sufficient for Explanation*, «Philosophy of Science», 74 (2007), pp. 481-500.

tions of singular events, the causal requirement does *not* follow from the unification requirement…».[39]

Schurz, however, does not see this as damaging to the unificationist account because he believes causal theories are only themselves justified by their unifying power. In other words, to explain events Explanatory Unification requires an appeal to causal theories, but on the theoretical level, causal theories are themselves only justified by their unifying power. Nonetheless, Explanatory Unificationists need not take this route. In fact, I think that both Barnes and Schurz are wrong in their assessment of Explanatory Unification's ability to account for asymmetry. Kitcher already has available, via appeal to explanatory stores, a strategy for basing causality of particular events on unification.

To explain, Kitcher's immediate response to the tower-shadow asymmetry problem is to widen the scope of phenomena to all objects of length and not just tower-lengths. From this, he can formulate two patterns: The O&D pattern and the SBE pattern. The O&D pattern can be repeated over and over to a *wide range of phenomena* (people, flagpoles, mountains, particles, etc.). Thus, even though SBE can explain the height of the tower by the length of the shadow, the SBE pattern is not a genuine explanation because there are other ways, namely the O&D pattern, to derive the same conclusion but with more unifying power. The key to Kitcher's analysis, then, is in widening the scope of phenomena under consideration. Doing so easily allows us to see that SBE is less unifying, for not all objects of length cast shadows. Furthermore, because SBE fails to explain the length of all objects, whereas Kitcher argues O&D can, an explanatory store E(K) will be more unifying with only the O&D pattern rather than with both or just the SBE.

But, even if this answer is able to account for the tower-shadow example, one has only to point out that there may be other asymmetrical examples that are not so easy to resolve. In other words, the fact that not all objects cast shadows was able to save Kitcher's account on that score, but what about situations in which there are two equally unifying explanations? Or, let us just imagine we are in a world where all objects *do* cast shadows. What would Kitcher say then? Putting aside the possible world in which all objects do cast shadows, one could argue equally as effectively that the tower has a complex dispositional property. This property is «the disposition to cast a shadow of such-and-such a length on such-and-such a surface if illuminated by a light-source at such-and-such an elevation above the surface».[40] From this, we can derive a dispositional shadow pattern to replace SBE. Let us call this pattern DSE. This, one could argue, has an equally unifying pattern as O&D. And if

[39] G. SCHURZ, o.c., p. 100.

[40] P. KITCHER, *Explanatory Unification and Causal Structure*, cit., pp. 485-486.

one questions whether this pattern applies to all objects with length, one need only add to the pattern a disjunctive predicate of the form:

«X has the disposition to cast a shadow if illuminated by a light source or x has the disposition to produce an absorption pattern if x is suitably coated and irradiated or x has the disposition to cast a shadow if x is covered with opaque material or x has the disposition to cast a shadow if x is sectioned and unrolled or x has the disposition to cast a shadow after x has been treated to block its own light sources or…[etc]».[41]

The critic of the unificationist view can in this way supply two equally unifying patterns. What is Kitcher now to do? Kitcher's first line of response is to claim that the above dispositional property is an 'unprojectable predicate'. That is, it is a property that has been gerrymandered to include an «artificial congeries of properties as a single characteristic».[42] Furthermore, because there is no common dispositional property that can be employed for all objects, they do not fit into a single genuine pattern.

However, Barnes argues that there are numerous other examples of argument patterns that do not rely upon unprojectable predicates and that are "maximally unifying" but non-explanatory. The three types of counterexamples Barnes uses are temporally symmetric closed systems, evidentiary arguments, and unexplained facts. All of these examples show, Barnes argues, that under Kitcher's account there are backward explanations that go from effects to causes, which are more unifying than forward explanations that proceed from causes to effects. Consequently, backward explanations are genuine explanations according Explanatory Unification. Todd Jones, however, believes Barnes is wrong on this score. Explanatory Unification is able to account for asymmetry in these backward or retrodictive pseudo-explanations. This is so because the theory of Explanatory Unification rests on two important theses:

«1) In cases where the only way to derive a precise description of some phenomenon is to retrodict it from later information, there are other, more unifying, forward-looking patterns which can partially derive these conclusions and are preferred on unification grounds.

2) The forward-looking derivations of conclusions, even if only partial, help unify our knowledge because the patterns involved belong to related families of patterns. Membership in these larger families make forward-looking patterns preferred on unification grounds».[43]

[41] *Ibidem*.

[42] By a "projectable predicate" Kitcher means something which refers to a natural kind. So, an "unprojectable predicate" does not refer to a natural kind (E. Barnes (eupa), o.c., p. 564).

[43] T. Jones, *How the Unification Theory of Explanation Escapes Asymmetry Problems*, «Erkenntnis», 43 (1995), pp. 229-240, p. 231.

Given these two important features, none of Barnes' examples count as unifying argument patterns or explanations. Jones is able to refute each of these supposed counterexamples by appealing to "epistemologically intermediate" accounts, whereby although the explanation provided is partial or speculative, it is more unifying. Jones explains:

«There are several reasons that the partial account should be considered the more unifying derivation, and would thus be counted as the truly explanatory account by unificationists. The guiding intuition of the unification perspective is that we should try to derive as many conclusions as we can, using the same argument patterns again and again. A partial account tells us a great deal about numerous features of the conclusion, without having to add any new patterns to our special maximally unifying set. Additionally, the less precise, more schematic premises used in partial explanations employ what might be called 'placeholder' terms. …The use of placeholder terms not only gives us partial conclusions, but also guides us in our gathering of new information, telling us what to look for to enable us to generate more precise conclusions».[44]

Additionally, Barnes' claim that the Newtonian Predictive Pattern is equally as unifying as a Newtonian Retrodictive pattern (where later states of the system are used to derive earlier states) can also be refuted by appeal to "families" of patterns. The idea here is that one way to unify our knowledge is by using the fewest number of patterns. But this is not the only way our knowledge can be unified: it can also be unified through using similar patterns belonging to the same "family." Hence, some derivation patterns are more unifying by their membership in a family of patterns that derives far more conclusions than any rival patterns or rival families of patterns. Jones then goes on to explain that the Newtonian Predictive Pattern belongs to the family of O&D patterns. So, even if one can use the Newtonian Retrodictive Pattern to derive the same conclusion, it does not belong to this family of patterns and is thus less unifying.

The obvious objection here, however, is that the Newtonian Retrodictive Pattern may belong to an equally unifying family of "backward" derivations. If this is the case, then Kitcher's problem reappears. Jones, however, argues that even if there were backwards family patterns, these families would be less unifying than forward-looking patterns because the backward patterns cannot derive conclusions about the present and future. Moreover, even if one had access to future events, these backward patterns cannot also derive conclusions about the past.[45] Thus, Jones concludes, forward-looking families of patterns will always be more unifying than retrodictive families of patterns.

[44] *Ibidem*, pp. 234-35.

[45] This is because «the second law of thermodynamics guarantees that for things looked at from an aggregate 'macro' perspective, increases in entropy will continually wipe out the traces of past events» (*ibidem*, p. 239).

Hence, Kitcher's unification account is saved from Barnes' charges that it cannot account for causal asymmetry.

Accordingly, Explanatory Unification *is* a viable theory for the explanation of both laws and events. Granted, there are other problems that Kitcher's account of Explanatory Unification faces that need to be resolved such as how one is able to determine what fits in each explanatory store in addition to the pragmatic consideration of how one would cognitively be able to access the unifying power of a possibly infinite explanatory store; but, these are issues that can perhaps be resolved with a greater refinement of Kitcher's unifying method. What is important is the fact that Explanatory Unification can account for causal asymmetry, spurious unifications, and explanations of laws.

5. Further Issues for Explanatory Unification

Obviously, there remain additional questions one must consider before one is able to evaluate the overall success of Explanatory Unification. Some of these questions include:

1) Is Salmon is right in claiming the causal mechanistic and the unification views are compatible, or do the commitments that lead one to accept the causal view force one to reject the unification view?[46]

2) If we grant that laws are better explained by the unification view and events or statistical facts are better explained by a causal view, what does this tell us about the nature of explanation?

3) Finally, what does the utilization of two differing views say about the ability of science to be understood or unified?

I am not prepared here to provide answers to these questions, as treatment of these issues is beyond the scope of this present paper. Rather, I offer these questions to make clear that the issue of Explanatory Unification's success as an adequate theory of explanation does not merely reside in its ability to account for trivial deductions or asymmetries. To the contrary, until the nature of scientific explanation is itself better understood, this judgment will have to be reserved. Explanatory Unification, however, has numerous virtues, one of which is its ability to render coherent the nature of scientific understanding, which is no small task indeed.

Unification also has a tremendous amount of support in the scientific community. Salmon, for example, asserts that unification is a fundamental goal

[46] For some recent defenses of the compatibility of the causal mechanistic account with the unificationist account, see: R. Skipper, *Selection and the Extent of Explanatory Unification*, «Philosophy of Science», 66 (1999), pp. 196-209; M. Strevens, *The Causal and Unification Approaches to Explanation Unified-Causally*, «Nous», 38 (2004), pp. 154-176; E. Weber and J. van Bouwel, o.c.; E. Weber and M. van Dyck, *Unification and Explanation*, «Synthese», 131 (2002), pp. 145-154; and J. Woodward, *Making Things Happen: A Theory of Causal Explanation*, Oxford UP, Oxford 2003.

of explanation. Hempel also agrees that unification is important to scientific explanation, stating that «a worthwhile scientific theory explains an empirical law by exhibiting it as one aspect of more comprehensive underlying regularities, which have a variety of other testable aspects as well, i.e., which also imply various other empirical laws. Such a theory thus provides a systematically unified account of many different empirical laws».[47] Hempel further claims that, «what scientific explanation, especially theoretical explanation, aims at is not [an] intuitive and highly subjective kind of understanding, but an objective kind of insight that is achieved by a systematic unification, by exhibiting the phenomena as manifestations of common, underlying structures and processes that conform to specific, testable, basic principles».[48]

Finally, there are other noteworthy advantages in accepting a unification account of scientific explanation. First, unification is intimately tied to understanding and as we have seen, understanding is an important part of scientific explanation. Second, unification bypasses the difficulties presented by Hume's analysis of causation. Third, the thesis of Explanatory Unification resolves Hempel's difficulty in explaining laws with the D-N model, or at least comes quite close. Fourth, where the nomic expectability approach and the causal approach are mutually inconsistent, Explanatory Unification is compatible with either view as a supplement to their local analyses. Thus, an acceptance of Explanatory Unification does not entail a rejection of the causal approach; they may be two different ways of interpreting the ideal explanatory text. Finally, though it can be compatible with other theories, Explanatory Unification is also able to explain laws and events on its own. There appear to be no insuperable challenges to the coherence or consistency of the thesis of Explanatory Unification, and it is adequately able to respond to both the issues of asymmetry and spurious unifications. Although I believe I have successfully refuted the criticisms of Barnes in demonstrating that the thesis of Explanatory Unification is able to explain laws and account for causal asymmetry, there still remain many issues to be addressed before a final assessment of Explanatory Unification's success as a theory of scientific explanation can be made. It is my hope that with future refinements of the technical aspects of the theory that these problems with be resolved as well.

Abstract: *This paper represents a response to the criticisms made by Eric Barnes in "Explanatory Unification and the Problem of Asymmetry" and "Explanatory Unification and Scientific Understanding" against the thesis of Explanatory Unification. This paper responds to Barnes' two main criticisms, that of derivational skepticism and casual asymmetry, and*

[47] C. Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science*, cit., p. 444.

[48] Idem, *Philosophy of Natural Science*, Prentice Hall, Englewood Cliffs 1966, p. 83, taken from P. Kitcher, *Explanatory Unification*, cit., p. 508.

successfully refutes his objections. This paper also defends the plausibility of the unificationist account of scientific explanation because of its ability to render coherent the notion of scientific understanding, focusing in particular on the work by Michael Friedman and Philip Kitcher.

KEYWORDS: *unification, scientific explanation, derivational skepticism, causal asymmetry, philosophy of science, Kitcher, Friedman, Barnes.*