Inaugurating Understanding or Repackaging Explanation?*

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Recently, several authors have argued that scientific understanding should be a new topic of philosophical research. In this article, I argue that the three most developed accounts of understanding—Grimm's, de Regt's, and de Regt and Dieks's—can be replaced by earlier ideas about scientific explanation without loss. Indeed, in some cases, such replacements have clear benefits.

1. Introduction. If the first decade is any indication, understanding promises to be a lively topic among philosophers of science throughout the twenty-first century.[1] Nor is it surprising that scientific understanding should garner this attention. Throughout history, many prominent scientists have highlighted the centrality of understanding to their enterprise. To choose but one instance, Schrödinger writes, "What are the peculiar, special traits of our scientific world-picture? About one of these funda-

*Received October 2010; revised January 2011.

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‡This article was written at the University of Pittsburgh's Center for Philosophy of Science during a sabbatical funded by Middlebury College. I thank both institutions for their support. This article has also benefited from conversations with Pierluigi Barrotta, Jim Bogen, Henk de Regt, Heather Douglas, Benny Goldberg, Hylarie Kochiras, Bert Leuridan, P. D. Magnus, Ken Manders, Sandy Mitchell, John Norton, Richard Samuels, Samuel Schindler, Susan Sterrett, J. D. Trout, Peter Vickers, Ioannis Votsis, and Jim Woodward.

1. See Lacey (1999), Trout (2002, 2005, 2007), de Regt (2004, 2009a), de Regt and Dieks (2005), Grimm (2006, 2008, 2010), de Regt, Leonelli, and Eigner (2009), and Khalifa (2011). I will not discuss parallel developments in epistemology (see, e.g., Kvanvig 2003).

Philosophy of Science, 79 (January 2012) pp. 15–37. 0031-8248/2012/7901-0002$10.00
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https://doi.org/10.1086/663235 Published online by Cambridge University Press

mental features there can be no doubt. It is the hypothesis that the display of Nature can be understood" (1954, 90).[2]

Despite the newfound philosophical enthusiasm for scientific understanding, the scholarship has its problems. In particular, I argue that current ideas about scientific understanding can be replaced by earlier ideas about scientific explanation without loss. Indeed, in some cases, such replacements have clear benefits.

In section 2, I provide some relevant background about the neglect of understanding among earlier philosophers of science. Among other reasons, earlier generations of philosophers of science took concepts of understanding to be redundant given their accounts of explanation. After generalizing and updating this idea, I use it as a foil against the most promising accounts of understanding. In section 3, I argue that Stephen Grimm's account of understanding can be replaced by James Woodward's account of explanation without loss. In section 4, I argue that Henk de Regt's work also makes no advance over the various explanatory literatures that he draws on. Finally, in section 5, I argue that de Regt's earlier collaborative work with Dennis Dieks is susceptible to some counterexamples that a pluralistic model of explanation would avoid.

2. Background. Several philosophers of science have observed that understanding and related concepts (e.g., intelligibility) play important roles in scientists' accounts of their practices, yet these concepts have garnered little philosophical attention.[3] Furthermore, several claims about understanding have strong intuitive force, for example, that scientists aim to understand various natural phenomena or that good explanations provide us with understanding.

Since these are not recent developments in the history of science, why did earlier philosophers of science neglect understanding as an area of research? A quick review of the literature suggests two reasons. First, many thought that understanding was irrelevant because it is a merely psychological or pragmatic phenomenon of no epistemic weight. While Hempel (1965) voiced this concern, its contemporary guise comes in Trout's (2002, 2005, 2007) recent charges that the sense of understanding is a highly unreliable cognitive faculty.

While debates about that issue are anything but resolved, I bracket them to emphasize another less heralded reason earlier philosophers of

2. Similar quotations from other scientists can be found throughout the works in n. 1.

3. I follow my interlocutors in focusing on understanding in the natural sciences, e.g., a scientist's understanding of gravity or why the heart pumps blood.

https://doi.org/10.1086/663235 Published online by Cambridge University Press

science passed over understanding.[4] On the old view, if understanding was not merely psychological afterglow, it was nevertheless redundant, being replaceable by explanatory concepts without loss. Roughly, the idea was that understanding amounts to adequately representing the information demanded by one's preferred model of explanation.

For example, Hempel (1965, 337) asserts, "the [deductive-nomological] 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." Of course, Hempel equated explanation with deductive-nomological (DN) arguments, so this says little more than that understanding tracks with explanation. But such a view is not limited to DN accounts of explanation. Salmon, a leading advocate of the causal-mechanical model of explanation, writes, "causal processes, causal interactions, and causal laws provide the mechanisms by which the world works; to *understand* why certain things happen, we need to see how they are produced by these mechanisms" (1984, 132; my italics). Similarly, unificationists hold that understanding consists in possessing unifying explanations, and so on and so forth.

We can generalize the thesis that understanding is redundant given a theory of explanation by introducing the following Explanatory Model of Understanding:

> (EMU) Any philosophically relevant ideas about scientific understanding can be captured by philosophical ideas about the epistemology of scientific explanation without loss.

If EMU is correct, we are welcome to use the word "understanding," but we should realize that we are just relabeling the explanation literature. In that case, the recent enthusiasm about understanding simply reinvents explanatory wheels.

Several points about EMU deserve further attention. While EMU echoes earlier ideas that understanding is largely redundant given a theory of explanation, it develops those ideas in two significant ways. First, it brings certain epistemological dimensions into relief (sec. 2.1). Second, it is compatible with explanatory pluralism (sec. 2.2). Finally, it dispenses with some pretheoretic intuitions about understanding (sec. 2.3).

2.1. Explanatory Knowledge. Intuitively, understanding is a mental state; explanation is not. While Hempel and Salmon both tacitly ac-

4. For critiques of Trout's view, see de Regt (2004, 2009a, 2009b), de Regt and Dieks (2005), and Grimm (2009).

https://doi.org/10.1086/663235 Published online by Cambridge University Press

knowledge this difference,[5] EMU explicitly addresses it by juxtaposing the epistemology of explanation with theories of understanding: like understanding, knowledge of an explanation is a mental state. As a result, EMU treats different aspects of this explanatory knowledge as capable of reaping the same philosophical rewards as understanding. While I advance no precise epistemological position here,[6] it suffices for my purposes to treat such knowledge as involving the possession of rich, accurate, and detailed beliefs about an explanation.[7] Two distinct segments of the explanation literature help to fill out this picture.

First, philosophers of science have provided fairly precise analyses of different forms of explanation (e.g., Hempel 1965; Salmon 1984; Kitcher 1989; Machamer, Darden, and Craver 2000; Woodward 2003).[8] Detailed and accurate explanatory knowledge then involves true beliefs about most of the information characteristic of a philosophical model of explanation. For example, EMU treats detailed and accurate knowledge about a DN explanation as involving true beliefs about a phenomenon, initial conditions, laws of nature, and their inferential relations.

Furthermore, both epistemologists and philosophers of science have discussed the relationship between explanation and justification (e.g., Sellars 1963; Harman 1973, 1986; Thagard 1978, 1992; Rosenberg 1980; Lycan 1988, 2002; Risjord 2000, chap. 4; Lipton 2004). Simplifying grossly, I note that these authors agree that good, well-justified explanations optimize the virtues (e.g., simplicy, power, consistency, fecundity, fit with data) of theories or systems of belief, typically by cohering with other claims within that system. Thus, having rich explanatory knowledge amounts to having a highly virtuous or coherent set of beliefs about an explanation.

To summarize, explanatory knowledge amounts to having a mostly true and highly virtuous set of beliefs about the information constituting an explanation. As we have seen, a substantial body of literature discusses

5. For example, both passages above suggest that understanding is a relationship between a person ("us") and an explanation, as would be the case if understanding were a mental state.

6. In particular, I say nothing about anti-Gettier conditions. See Grimm (2006) and Khalifa (2011) for more detailed arguments that understanding is a species of explanatory knowledge.

7. Some theorists (e.g., Salmon 1984) hold that explanations are things in the world (e.g., causal interactions, processes, or mechanisms). EMU can incorporate these theorists' ideas by claiming that, in certain contexts, understanding can be replaced by knowledge of these worldly things (rather than the things themselves). Hereafter, I leave this implicit.

8. Salmon (1989), Woodward (2002), and Cartwright (2004) provide good reviews of these and other analyses of explanation.

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different aspects of this knowledge. EMU asserts that this literature can replicate any philosophical insights claimed by theorists of understanding, thus making talk of understanding dispensable.

2.2. Explanatory Pluralism. Unlike the ideas expressed by Hempel and Salmon above, EMU is compatible with a pluralistic approach to explanation. For instance, EMU is consistent with DN explanations being appropriate in some contexts, causal explanations in others, and unificationist explanations in still others.[9] Such a pluralistic approach to explanation might invite charges that I am availing myself to an overly permissive notion of explanation. However, I assuage this worry in two ways.

First, for the purposes of dialectical effectiveness, I will always assume the same models of explanation as my interlocutors. Thus, when discussing Grimm, I follow him in adopting Woodward's model of causal explanation; my discussions of de Regt echo his focus on Hempel and Cartwright, and my discussions of de Regt and Dieks (R&D) follow them in considering both causal and unificationist accounts of explanation. Closely related, I use the examples that they (and most others) readily accept as explanatory. As a result, none of my interlocutors are entitled to raise this charge against me since we are using explanation in the same way.

Second, the issue at hand is not whether explanatory monism or pluralism is correct but whether understanding can be reduced to explanation. Since the examples used here are uncontroversial cases of explanation, they ought to satisfy the requirements of any theory of explanation, including some grand unified theory of explanation. Hence, the arguments below suggest that understanding is redundant if explanatory monism is true. Alternatively, it is perfectly consistent to claim that there is more than one concept of explanation while still holding fast to EMU. This would just mean that more than one concept of explanation is needed to accommodate the philosophically interesting ideas claimed as understanding's province. Thus, either explanatory monism or pluralism is compatible with EMU.

2.3. EMU's Initial Attractions and Opening Shots. While the new friends of understanding have recognized the need to distinguish themselves from scholars of explanation, the threat posed by EMU has gone largely unnoticed. In particular, EMU makes quick work of some of the most pressing puzzles for a theorist of understanding.

9. Achinstein (1983), Risjord (2000), Thalos (2002), Douglas (2009), and Khalifa (2010) defend explanatory pluralism.

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First, EMU provides a nonpsychological account of understanding, according no weight to the "sense" or "feeling" of understanding. Regardless of whether a person experiences a Eureka moment, a headache, a bout of depression, or a dizzy spell, so long as she knows of a good and correct explanation, EMU states that she understands. As such, if EMU is true, understanding is not merely psychological. This defuses the challenges posed by Trout's recent work.

Second, EMU unpacks many of the slogans that might prompt one to think understanding requires further explication, albeit in a deflationary manner. For instance, consider R&D's complaint about reducing understanding to explanation: "Nowadays many authors claim that scientific explanations are the means to achieve understanding, and defend a particular model of explanation by appealing to its alleged understanding-providing virtues. . . . However, none of them provides an account of what understanding consists in, in order to show *how* it is produced by scientific explanations. Usually, authors merely state that their favorite type of explanation furnishes understanding without any justification" (de Regt and Dieks 2005, 143). There are really two issues in this passage. First, there is an issue about whether a single account of explanation can identify something that all good explanations provide. While Hempel and Salmon certainly answer this in the affirmative, EMU plays no "favorites" about a model of explanation, so R&D's charges of parochialism do not apply to it.

Second, there is a question about what explanations are supposed to "provide," "produce," "furnish," or be a "means to achieving." EMU adopts a deflationary position toward this idea: good explanations simply produce explanatory knowledge. On this view, good DN explanations provide knowledge that a particular claim is a deductive consequence of a law of nature, good causal explanations produce knowledge of causes, and so on. There is nothing further that explanations need to provide.[10]

This might disappoint those who think that there must be a single theoretically interesting concept that unifies different accounts of explanation. However, EMU questions the wisdom of that impulse: an explanation provides understanding just in case it is known, and such knowledge does not require the extra philosophical scaffolding that advocates of understanding suggest. While largely deflationary in tone, EMU does not completely trivialize this problem, as not all explanations provide explanatory knowledge. For instance, EMU entails that only explanations that are mostly true, theoretically virtuous, and knowable can provide

10. Similarly, others claim that we judge potential explanations according to the understanding they would produce (Lipton 2004). Analogous arguments apply.

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understanding. As a result, it urges understanding's champions to state what is deficient about this picture.

Now to be sure, there are cases in which this explanatory knowledge is modest. For instance, one may come to know that natural selection explains why species evolve through the testimony of an expert, while being ignorant about most of the details concerning natural selection and evolution. While those wishing to inaugurate understanding might claim that this person can explain why species evolve even though he does not understand it, EMU offers a different diagnosis. Both understanding and explanatory goodness come in degrees; EMU suggests that degrees of understanding track with degrees of explanatory goodness. Advocates of EMU can then claim that the person in this example has a modest amount of understanding precisely because he does not have a very detailed explanation of why species evolve, but more detailed knowledge about this explanation would result in "fully" understanding evolution. In this way, fully understanding a phenomenon would just be having very rich, accurate, and detailed beliefs about its explanation.

Similarly, EMU deflates many other slogans that might motivate a philosophical inquiry into understanding. If EMU is correct, science aims to understand nature simply because science aims to explain natural phenomena. Similarly, it implies that understanding is an aim of explanation simply because scientists purport to explain things with the intention that those explanations provide or constitute explanatory knowledge.

Given EMU's initial attractions, what more could a theorist of understanding ask for? I will argue that current theorists of understanding have not answered this question and are susceptible to EMU attacks. In short, the current literature on understanding can be replaced by the current ideas about explanation without loss. In offering these arguments, I restrict my attention to current accounts of understanding, remaining agnostic about EMU's long-term prospects. Thus, if my arguments succeed, I have not delivered a deathblow to philosophical research into scientific understanding. Rather, I have clarified its burdens of proof.

While the scientific understanding literature is young, in my estimate, there are three plausible proposals concerning the nature of scientific understanding—those offered by R&D (de Regt and Dieks 2005), de Regt (2009a, 2009b), and Grimm (2010).[11] As I now show, these views cannot meet EMU's challenge.

3. Critique of Grimm. Stephen Grimm (2010, 340–41) summarizes his

11. So far as I know, these are the three most developed accounts of scientific understanding. To repeat, there are epistemological theories of understanding that will not be discussed here.

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view of understanding as "the ability to anticipate how changes in the value of one of the variables . . . would lead to (*ceteris paribus*) a change in the value of another variable," plus the ability to apply general expressions of these dependency relations between variables to particular cases. For example, suppose that someone recognizes (via Bernoulli's principle) that the shape of an airplane's wing (curved on top and flat on the bottom) creates a difference in the velocity of air on the top and the bottom of the wing, such that the pressure exerted by the slower-moving air along the bottom of the wing is greater than the pressure exerted along the top of the wing. As a result of this difference in pressure, flight is possible. Moreover, assume that the person can see that changes in the shape of the wings or in the pattern of airflow would result in the plane not being able to fly. Intuitively, this person understands why planes fly, just as Grimm proposes.

I will not assess whether Grimm provides an adequate model of understanding, for even if he does, he has made no departure from things already said in the explanation literature. We can get a hint of this by observing Grimm's acknowledgment that "Woodward (2003) appropriately stresses . . . the general ability [involved in explanation] seems to carry with it the specific ability to answer 'what-if-things-had been-different?' questions" (Grimm 2010, 341 n. 23). This is an understatement—Grimm's account of understanding seems to be little more than a consequence of Woodward's analysis of explanation:

> (*EXP*) Suppose that M is an explanandum consisting in the statement that some variable Y takes the particular value y. Then an explanans E for M will consist of (a) a generalization G relating changes in the value(s) of a variable X (where X may itself be a vector or n-tuple of variables X_i) and changes in Y, and (b) a statement (of initial or boundary conditions) that the variable X takes the particular value of x. A necessary and sufficient condition for E to be explanatory with respect to M is that (i) E and M are true or approximately so; (ii) according to G, Y takes the value y under an intervention in which X takes the value x; (iii) there is some intervention that changes the value of X from x to x' where $x \neq x'$, with G correctly describing the value y' that Y would assume under this change, where $y \neq y'$. (Woodward 2003, 203)

Condition iii of EXP describes Grimm's requirement that understanding involves anticipating how changes in one variable (X) affect changes in another (Y), or what Woodward refers to as the answer to a "what-if-things-had-been-different question." EXP's conditions *b* and ii articulate Grimm's other requirement on understanding: that a general principle

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(*G*) applies to a particular case (where *x* and *y* denote the respective values that variables *X* and *Y* take in a particular case).

Of course, there is one important difference between Grimm's account of understanding and Woodward's account of explanation. Grimm has a further interest in the mental states and cognitive abilities required for a person to use the explanatory information that Woodward presents in EXP. But covering this difference requires a pretty modest leap: Grimm holds that if a person can accurately represent the explanatory information in EXP, then she can understand *M*. A Woodwardian who also endorsed EMU would accept precisely the same idea.

The strong similarity between Grimm's and Woodward's views suggests that the former is reducible to the latter. In effect, Grimm assumes that something satisfying Woodward's criteria for explanation is understood. This is not a new theory of understanding; it is simply an endorsement of Woodward's model of explanation. Hence, Woodward's account of explanation already captures anything philosophically interesting about Grimm's account of understanding.[12]

As I see it, Grimm might distance himself from Woodward in one of two ways. First, unlike Woodward, Grimm makes no explicit reference to interventions when discussing the counterfactual dependency relations characteristic of understanding. Second, since he only appears to accept that Woodwardian explanation is sufficient, but not necessary, for understanding, it is open to Grimm to argue that there are cases of understanding without explanation. Perhaps there are good arguments along one or both of these lines. However, Grimm has not offered these arguments. This suffices to establish my claim about the current literature on understanding: currently, Grimm has not provided us with any reason to think that equating understanding with Woodwardian explanation would have any negative consequences.

Moreover, both of these responses face significant difficulties that might prompt us to stick with EMU. For instance, Woodward (2003, 220–21) explicitly considers variations of EXP that do not refer to interventions and treats them as instances of noncausal explanations. If Woodward is correct, then these cases simply feed EMU, thereby blocking the first kind of rebuttal we suggested for Grimm. Similarly, if Grimm were to pursue the second kind of rebuttal we suggested, he would need to show that something satisfies EXP but is not an explanation. But because EMU is not limited to Woodward's account of explanation, Grimm would have to argue that the counterexamples to Woodward's view also are not legitimate instances of another model of explanation.

12. In saying this, I do not judge the adequacy Woodward's model of explanation, only its bearing on Grimm's account of understanding.

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Consequently, I think Grimm is more charitably read as an advocate of EMU, not an inaugurator of understanding. Indeed, when Grimm talks about understanding's relationship to explanation, he is quite cautious not to claim that understanding is a goal of explanation but, rather, a goal of explanatory inquiry; that is, "when we are puzzled about why things are a certain way, we pose explanation-seeking why-questions to try to resolve our puzzlement. And the goal of these why-questions—the goal of these inquiries—is understanding" (Grimm 2010, 337). If Grimm took understanding as the goal of explanation, this would imply that explanation and understanding are not identical, for if G is the goal of A, then $G \neq A$. For instance, the goal of playing chess is to checkmate one's opponent, but playing chess is not identical to checkmating. Instead, Grimm claims that understanding is the goal of explanatory inquiry. This is consistent with our earlier, EMU-inspired gloss saying that scientists intend for their proffered explanations to provide rich, accurate, and detailed knowledge. Thus, I suggest that Grimm should be regarded as endorsing EMU.

4. Critique of de Regt. Henk de Regt (2009a, 2009b) offers a different account of understanding, but it also marks no advance over EMU. Indeed, at first glance, de Regt capitulates much to EMU, by asserting that "understanding a phenomenon [is identical with] having an appropriate explanation of the phenomenon" (de Regt 2009a, 588; 2009b, 25). However, de Regt also highlights two features of understanding that might distinguish it from explanation. First, de Regt claims that having an adequate explanation of a phenomenon requires understanding how to use a theory (i.e., a skill). Call this the *skill condition*. Second, de Regt claims that the theory in question must be user-friendly or "intelligible." Call this the *intelligibility* condition.

Intuitively, both the skill and the intelligibility conditions seem to mark departures from EMU. Theorists of explanation have said little about skills and intelligibility, and there appear to be several examples in which the absence of skill indicates a lack of understanding, even when explanatory information is present. For example, students frequently founder when they have to apply their explanatory knowledge to novel cases, a point often thought to reflect on their lack of skill and understanding. Similarly, a person who finds a theory unintelligible seems poorly positioned to explain phenomena with that theory.

Despite these initial attractions, I will now argue that the skill condition is either false or trivial. In either case, EMU wins the day. Similarly, the intelligibility condition amounts to a rehash of theoretical virtues that have long been identified as explanatory criteria.

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4.1. The Skill Condition. De Regt acknowledges the challenge posed by EMU, which he associates with an "objectivist" account of understanding: "Insofar as objectivists are willing to discuss *scientific* understanding, they identify it with explanation, thereby making it redundant" (2009a, 587). He then asserts that skills play a prominent role in debunking objectivism: "understanding is based on skills and judgments of scientists and cannot be captured by objective algorithmic procedures. It is therefore incompatible with the objectivist conception of explanation and understanding" (587).[13]

This leads him directly to the skill condition: "in order to achieve understanding of phenomena by constructing explanations, one needs a nonobjective, pragmatic kind of understanding" (de Regt 2009b, 26). Pragmatic understanding is then defined in terms of "being able to use the theory" (i.e., skills; de Regt 2009a, 588; 2009b, 25).

The skill condition faces two difficulties. First, it does not appear necessary for understanding. Second, even if it is necessary for understanding, it may be trivial. To see why the skill condition may be unnecessary, let us consider de Regt's discussion of Hempel. De Regt differentiates his pragmatic account of understanding from Hempel's objectivist counterpart along the following lines: "That understanding is pragmatic . . . implies that scientist S_1 may understand P while S_2 does not, even if they both possess [explanation] E (the difference in understanding being due to individual differences between S_1 and S_2 or between the relative contexts in which they operate)" (de Regt 2009a, 586). De Regt takes skills to be important contextual determinants of what a person understands. By contrast, Hempel denies that differences in skill bear on a philosophically relevant notion of understanding. Furthermore, because Hempel also endorses some form of EMU, Hempel's account of understanding just is "possessing" a DN explanation, to use de Regt's term.

This still leaves a rather delicate issue about what Hempel takes this "possession" to be. On de Regt's interpretation, Hempel takes it to be knowledge of the explanans and explanandum: "a student may have memorized Bernoulli's principle and have all the background conditions available but still be unable to use this knowledge to account for the fact that jets can fly. The extra ingredient needed to construct the explanation is a *skill*: to construct deductive arguments from the available knowledge" (de Regt 2009a, 588; 2009b, 26).

In accordance with EMU, I will grant that Hempel takes knowledge as the basic mental state involved in possessing an explanation. Nevertheless, de Regt's interpretation is not entirely charitable, for Hempel's

13. A similar quotation can be found in de Regt (2009b, 25).

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account of understanding still requires more knowledge than that of the explanans and the explanandum. Consider the following quote: "The understanding [that scientific explanation] conveys lies in *the insight* that the explanandum *fits into, or can be subsumed under*, a system of uniformities represented by empirical laws or theoretical principles" (Hempel 1965, 488; my emphasis).

Clearly, the student does not have the "insight" to which Hempel refers; the student cannot see how facts about the jet's lift "fit" with Bernoulli's principle, much less a broader "system of uniformities." Hence, Hempel would require that the student know more than de Regt countenances. For not only must she know Bernoulli's principle and the jet's initial conditions (the explanans) and facts about the jet's lift (the explanandum), but she must also know that the explanans entails the explanandum. In Hempel's parlance, that is the "insight" about the "fit."

De Regt includes knowledge of the explanans and explanandum, but he omits the student's "possession" of the information concerning their inferential connection. Curiously, this knowledge perfectly plugs the gap in the student's understanding. Moreover, it is just more propositional knowledge and, thus, need not be "know-how" or a skill. As a result, there is a Hempelian treatment of the example that makes no essential appeal to the skill condition.

Furthermore, while Hempel's view refers to an *entailment* relation, we could plug in any explanatory relation we please (e.g., causal, unificationist). Thus, the preceding example could be generalized for any variant of EMU, such that understanding amounts to (*a*) knowing that the explanans is true, (*b*) knowing that the explanandum is true, and (*c*) for some *l*, knowing that *l* is the correct explanatory link between the explanans and the explanandum. This requires three points of clarification. First, my argument is unaffected by the fact that explanatory claims are often only approximately true in some sense. We could simply include the appropriate qualifications in these three conditions; for example *a* would read: "Knowing that the explanans is *approximately* true."

Second, condition *c* is EMU's alternative to the skill condition. Essentially, skills are replaced by propositional knowledge concerning explanatory details, for example, knowledge that Bernoulli's principle plus initial conditions entail facts about the jet's lift or that if the airflow were to change, the jet's flight path would change. More generally, explanatory links include entailment, causal, probabilistic, and statistical relations.

Finally, and most importantly, *a–c* leads us straight to the land of EMU: understanding would just be a kind of explanatory knowledge. Thus, we can bypass the skill condition without loss. Perhaps de Regt could argue that a person who satisfied *a–c* still does not really understand if she does not have a certain skill; for example, she cannot apply Ber-

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noulli's principle to new cases. However, so long as these new applications just amount to new explanations, proponents of EMU can claim that this is a difference in degree, not kind: the more that one can explain, the more one understands.

As before, I offer some disclaimers. First, I am agnostic about whether the alternative sketched by *a–c* provides an accurate account of understanding. Rather, it suffices for my purposes that de Regt provides no reason to think that we would lose anything by adopting it. Second, while the challenges I have raised are surmountable in principle, their solutions are not straightforward affairs, so we should not give de Regt a free pass.

For instance, de Regt could argue that whenever the propositional knowledge spelled out by *a–c* is gained without the exercise of certain skills, it does not constitute understanding. That would provide some evidence for the skill condition. However, de Regt does not provide us with this sort of example, and so we are still left wondering what we lose by replacing understanding with explanatory knowledge.

Moreover, there are potential difficulties with this kind of rebuttal, which brings me to my second major critique of the skill condition. Even if it is a necessary feature of understanding, it might very well be trivial once we introduce the explanatory considerations characteristic of EMU. For instance, even if we granted every bit of de Regt's preceding argument for the skill condition, the big upshot is that understanding a DN explanation requires deductive-reasoning skills.[14] But do we really need a theory of understanding to tell us *that*?

Of course, not all explanations are DN, as de Regt acknowledges by countenancing model-based explanation. In this latter context, de Regt adopts Cartwright's simulacrum account of explanation, which holds that "to explain a phenomenon is to construct a model that fits into the theory" (Cartwright 1983, 17). As with DN explanations, de Regt argues that certain skills are necessary for simulacrum explanations; in this case, the ability to navigate "a complex process involving approximations and idealizations" (de Regt 2009a, 591; 2009b, 29).

De Regt's arguments regarding simulacrum explanations are structurally analogous to his arguments regarding DN explanations. As a result, they suffer from the same two worries. First, one could simply plug in Cartwright's simulacrum model into the schema presented by *a–c* to produce an alternative account of understanding that makes no reference to skills. In this case, an understanding agent would need to know the explanandum, the explanans, and the details linking a model of the ex-

14. To repeat de Regt's quote from above, "*The* [my italics] extra ingredient needed to construct the explanation is a *skill*: to construct deductive arguments from the available knowledge."

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planandum to the basic framework of the theory. Second, just as we do not need a theory of understanding to tell us that DN understanding involves deductive-reasoning skills, it is not exactly newsworthy that constructing model-based explanations involves competence in approximating and idealizing.

As with Grimm, it is open to de Regt to argue that there are cases of understanding without explanation. Indeed, some kinds of approximation and idealization do not yield explanations, for example, when we are constructing certain predictive models. As before, I offer some words of caution. First, many nonexplanatory models of this sort are thought to be "black-boxy" and hence opaque to understanding. Second, it is unclear that de Regt can put these examples to work and still endorse the simulacrum account of explanation. Cartwright's account is very broad, counting any model of a phenomenon that fits into a theory as explanatory. Cases of approximating or idealizing that do not involve constructing such models—and that could still plausibly count as cases of understanding how to use a theory—are elusive, to say the least.

Thus, the skill condition—whether we examine deductive or simulacrum explanations—seems to face a deep tension. On the one hand, it might be eliminable given an elaboration of the propositional knowledge involved in an explanation. On the other hand, even if some of the skills cannot be captured by explanatory knowledge, they appear so thin as to trivialize understanding.

4.2. The Intelligibility Condition. Perhaps de Regt can bypass these worries if the second feature of his account of understanding—what we earlier referred to as the intelligibility condition—is not reducible to EMU.[15] As de Regt (2009a, 593) puts it, "scientific understanding of phenomena requires intelligible theories."[16] Given that he equates understanding a phenomenon with having an adequate explanation of it,[17] de Regt is committed to intelligibility being necessary for explaining phenomena. Obviously, much now hangs on de Regt's definition of intelligibility:

15. De Regt actually takes his appeal to intelligibility to be "a more precise characterization of the nature of and conditions for pragmatic understanding [i.e., the skills required to use a theory]" (2009a, 592). I have treated them as distinct to emphasize different difficulties with his account, and these difficulties remain regardless of whether the skill reduces to the intelligibility condition.

16. Similarly, he writes, "Scientists need intelligible theories in order to achieve scientific understanding of phenomena" (de Regt 2009b, 32).

17. Recall from above: "understanding a phenomenon [is identical with] having an appropriate explanation of the phenomenon" (de Regt 2009a, 588; 2009b, 25).

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> **Intelligibility**. The value that scientists attribute to the cluster of virtues (of a theory in one or more of its representations) that facilitate the use of the theory for the construction of models (de Regt 2009a, 593; 2009b, 31).

Piecing these ideas together, we get:

> If theory T explains phenomenon P, then scientists find that the virtues of T are useful (valuable, good) for constructing models.

However, since de Regt follows Cartwright in equating explanation and model construction, this appears no different than:

> If theory T explains phenomenon P, then scientists find that the virtues of T are useful (valuable, good) for explaining.

As mentioned in section 2.2, both epistemologists and philosophers of science have explored this idea. Indeed, de Regt's virtues include "accuracy, consistency, scope, simplicity, unifying power, and fertility" (2009a, 592; 2009b, 31)—the same virtues cited as criteria of the best explanation by these authors. So using only these ideas from the explanation literature, we can recover the intelligibility condition, just as EMU asserts.

As before, there are potential responses. For instance, we have already suggested that adopting something narrower than Cartwright's simulacrum model may be better suited for de Regt's purposes. Furthermore, some philosophers do not make any explicit link between the virtues and explanation (e.g., Kuhn 1977), but then it behooves de Regt to identify how the virtues are useful in achieving some nonexplanatory form of understanding.

Thus, we have seen that neither the skill condition nor the intelligibility condition give de Regt's account of understanding any distance from the explanation literature. Once we countenance that understanding a phenomenon just is knowing an explanation of it, the skill condition is either unnecessary or not illuminating. And the intelligibility condition simply reissues the virtues that have long been thought to be criteria of the explanatory theories. As a result, de Regt has not adequately met the challenge of EMU.

5. Critique of R&D. Finally, let us examine R&D's proposal, which involves two central claims. The first is their Criterion for Understanding Phenomena:

> (CUP) A phenomenon P can be understood if a theory T of P exists that is intelligible (and meets the usual logical, methodological, and empirical requirements; de Regt and Dieks 2005, 150).

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Here the parenthetical requirements are designed to restrict the analysis to scientific understanding based on scientific theories. Next, they posit a Criterion for the Intelligibility of Theories:

> (CIT) A scientific theory T is intelligible for scientists (in context C) if they can recognize qualitatively characteristic consequences of T without performing exact calculations (de Regt and Dieks 2005, 151).

CIT is motivated by the idea that understanding amounts to having a "feel" for a theory, and it echoes many prominent physicists' remarks on this topic.[18] Piecing these two ideas together, we get R&D's thesis about Understanding:

> (U) A phenomenon P can be understood if a theory T of P exists such that:
>
> *a*) T meets the usual logical, methodological, and empirical requirements; and
> *b*) Some scientist S (in some context C) can recognize qualitatively characteristic consequences of T without performing exact calculations.

R&D couple U with a related thesis about Explanation:

> (E) If a scientist S can explain a phenomenon P, then a theory T of P exists such that:
>
> *a*) T meets the usual logical, methodological, and empirical requirements; and
> *b*) S (in some context C) can recognize qualitatively characteristic consequences of T without performing exact calculations.

Combined, these two theses entail that if P can be explained, then P can be understood. R&D do not fall prey to the same problem that Grimm and de Regt faced with earlier theories of explanations. Rather, they take themselves to be transcending any commitment to a specific model of explanation (e.g., causal-mechanical or unificationist) "by presenting the outline of a general theory of scientific understanding, which intends to give a comprehensive account of the various types of explanation defended in the literature" (de Regt and Dieks 2005, 143).

However, I now argue that there is a problem with R&D's thesis about understanding (i.e., U); what I call the *problem of irrelevant insights*. Fur-

18. De Regt and Dieks cite Heisenberg (1927, 172) and Feynman, Leighton, and Sands (1965, 1) as proponents of this view of scientific understanding. Dirac is also credited with this view (Wilczek and Devine 1987, 102).

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thermore, the easiest way to solve this problem produces a difficulty with their thesis about explanation (E), what I call the *problem of improbable explananda*. By comparison, these difficulties evaporate when we adopt EMU.

5.1. The Problem of Irrelevant Insights. Note that U's antecedent makes no reference to P, save that T be a theory of P. Hence, one may be able to recognize another qualitatively characteristic consequence Q of T that has nothing to do with P, and, according to U, this suffices to generate understanding of P. That seems quite doubtful. This is the problem of irrelevant insights.

Let's illustrate this with an example. In the aftermath of the BP oil spill in the Gulf of Mexico, a Berkeley research team reported the discovery of a new species of "oil-eating" deep-sea psychrophilic gammaproteobacteria in late August 2010 (Hazen et al. 2010). Undoubtedly, there was a point in recent history (e.g., before the oil spill in April 2010) where there were many unrecognized consequences of our current microbiological theory concerning this particular species of gammaproteobacterium, for example, that it does not retain crystal violet in the Gram staining protocol.

However, at the same time that these consequences remained unrecognized, scientists could easily recognize that "Streptococcus pneumoniae is a bacterium" is a consequence of the same theory. According to U, simply because scientists can recognize that Streptococcus pneumoniae is a bacterium, it follows that "deep-sea psychrophilic gammaproteobacteria do not retain crystal violet in the Gram staining protocol" can be understood.

Since that seems very implausible, I assume that R&D intend something other than U. The most plausible proposal would replace b with:

> (b') Some scientist S (in some context C) can recognize P as a qualitatively characteristic consequence of T without performing exact calculations.

This would block the problem of irrelevant insights. Since the scientists did not recognize anything about gammaproteobacteria, they do not understand anything about these bacteria, either.

Furthermore, this interpretation is consistent with R&D's discussion of Boltzmann's understanding of the macroscopic properties of gases via the kinetic theory: "If one adds heat to a gas in a container of constant volume, the average kinetic energy of the moving molecules—and thereby the temperature—will increase. The velocities of molecules therefore increase and they will hit the walls of the container more often and with greater force. The pressure of the gas will increase. In a similar manner,

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we can infer that, if temperature remains constant, a decrease of volume results in an increase of pressure. Together these conclusions lead to a qualitative expression of Boyle's ideal gas law" (de Regt and Dieks 2005, 152). The phenomena to be understood are the relationships among temperature, pressure, and volume expressed by the ideal gas laws. The understanding consists of inferring a qualitative version of these laws from a qualitative formulation of the kinetic theory, as would be the case under b'.

5.2. The Problem of Improbable Explananda. This proposed solution to the problem of irrelevant insights is tentative, for it provides the seeds of R&D's undoing. Note that if we shift from b to b' in U, we need to make a corresponding shift in E. Otherwise, it does not follow that explanations entail understanding.

However, the resulting view about explanation faces some venerable problems, for it is one of many Hempelian ideas to face searching counterexamples. The most famous example on this front is that a person's having syphilis explains why he has paresis, yet only 25% of syphilitics suffer from paresis. As a result, one could not recognize paresis as a consequence of a theoretical claim about syphilis. Analogous examples appear throughout the special sciences. For example, in neuroscience, as little as 10% of all action potentials result in neurotransmitter release, but action potentials are regarded as the central causal mechanisms explaining neurotransmitter release (Bogen 2005; Craver 2007).

Surprisingly, R&D do not address these sorts of examples, despite the challenge they pose for their view. Given that they openly acknowledge the strong similarities their view bears to the DN model, and address several well-trodden problems concerning the sufficiency of that account, such as the barometer and flagpole problems (de Regt and Dieks 2005, 162–63), ignoring the signal challenge to the necessity of Hempel's model is a significant oversight.

Moreover, R&D's handling of the other counterexamples does not easily transfer to this case. For instance, when handling explanatory asymmetries, they follow van Fraassen (1980) in claiming that "it depends on the context whether the length of the flagpole makes it understandable how long the shadow is, or vice versa" (de Regt and Dieks 2005, 164). Whatever the merits of that approach, appealing to context in the syphilis example involves swallowing a bigger pill, as the challenge only requires that if Q explains P, then P is a consequence of Q. This does not require reference to context: the consequence relation is an issue of semantics, not pragmatics. If R&D seek to challenge that claim, then they are shouldering a rather significant burden of proof in the philosophy of logic.

Furthermore, even if R&D bit the bullet and insisted that the con-

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sequence relation is context sensitive, they invite the charge that understanding is epistemically suspect. If, in a particular context, one can "infer" that someone has paresis from the fact that he has syphilis despite the low conditional probability, then recognizing a consequence of theory is little more than forming psychological associations with that theory. R&D would then seem hard pressed to reconcile this with their claim that understanding is not "merely a (philosophically irrelevant) psychological by-product of scientific activity" (de Regt and Dieks 2005, 138).

5.3. Comparison with EMU. Perhaps R&D would propose something other than b' as a solution to the problem of irrelevant insights, but until they do, we have no reason to accept their view. This is especially pressing because neither this nor the problem of improbable explananda arises for EMU.

For instance, EMU dissolves the problem of irrelevant insights because no model of explanation would claim that recognizing "Streptococcus pneumoniae is a bacterium" as a theoretical consequence provides knowledge of an explanation (and hence understanding) of why "deep-sea psychrophilic gammaproteobacteria do not retain crystal violet in the Gram staining protocol." Similarly, friends of EMU can easily avoid the problem of improbable explananda. A person's having syphilis causes him to have paresis, and this is widely regarded as the relevant notion of explanation in this example, even if there is no further inferential relation.

Indeed, even if we grant that the explanation literature is as fragmented as R&D claim, advocates of EMU do not appear to fare any worse than R&D. In such a scenario, friends of EMU may claim that understanding and explanation are coextensive but that *explains* is a context-sensitive concept. While this is perhaps not terribly satisfying if one is looking for some deep unity in the explanation literature, it would be no worse than claiming that *understanding* is context-sensitive, as R&D do by referring to context C in their thesis about understanding. Furthermore, given that we have several well-developed models of explanation, this contextual view of EMU would have the benefit of offering a much more precise context-dependent parameter.

Thus, R&D's account of understanding faces a number of difficulties that we simply avoid by adopting EMU. In particular, the problem of irrelevant insights is endemic to their view, and a very plausible solution to that problem might lead to problems somewhere else, for example, the problem of improbable explananda. Simply by dispensing with the idea that understanding can be cashed out antecedently of explanation, these problems go away.

6. Conclusion. We have argued that the new literature on understanding

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can be replaced by its more venerable counterpart, the explanation scholarship, without loss. As I have stressed throughout, I do not think that this marks an early swan song for philosophical research on scientific understanding. I take my challenges as elucidating the parameters of a fledgling area of philosophical inquiry. With this in mind, I end on a more positive note, highlighting the kinds of strategies that I have suggested would help to set understanding on its proper course.

First, I think a good deal more needs to be done with cases of understanding without explanation, as I suggested in my discussions of Grimm and de Regt.[19] Perhaps the most suggestive cases arise in quantum mechanics: contemporary physicists' understanding of subatomic phenomena frequently involves grasping the limits of explanation, paradigmatically, the consequences of Bell's theorem. What exactly is understood in these sorts of cases? What can quantum mechanics tell us about more modest instances where, for example, our understanding involves grasping contingent explanatory limitations, such as potential rival explanations?

Second, while de Regt's account of skills faced serious difficulties, another account of skills may do the trick. Unfortunately, what philosophers have said about skills seems woefully impoverished for tackling issues about scientific understanding, but perhaps there are more fruitful resources in cognitive psychology (Larkin et al. 1980; Chi, Feltovich, and Glaser 1981; Ericsson 2006). This would have the benefit of being on equal naturalistic footing with Trout's work and, hence, capable of addressing Trout's concerns on his own terms.

Third, while R&D do not say enough to avoid EMU, further details about scientific contexts might help to pin down a suitable notion of understanding. Indeed, if skills turn out to be an important contextual determinant, then a fruitful area of research will examine how different specialists within a scientific discipline coordinate their cognitive resources or understand each other's work.[20]

Finally, I think there is a good deal more to be said about the relationship between coherence and understanding.[21] It is somewhat striking that even the precursors to EMU frequently refer to a "nexus" whenever they mention understanding: "All scientific explanation . . . seeks to provide a systematic understanding of empirical phenomena by showing that they fit into a nomic nexus" (Hempel 1965, 488). "My suggestion for

19. Lipton (2009) has the right idea on this front, although I think many of his examples are problematic. I am developing these ideas elsewhere.

20. For some gestures in that direction, see Darden and Maull (1977), Pickering (1984), Bechtel (1986), and Galison (1997).

21. Epistemological work on understanding, most notably Kvanvig (2003, 2009a, 2009b), has begun to develop this idea. See also Schurz and Lambert (1994).

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modification would be to substitute the words 'how they fit into a causal nexus' for 'that they fit into a nomic nexus'" (Salmon 1984, 19). Moreover, it seems to me that degrees of understanding frequently track with how well we can situate the object of our understanding within a larger nexus or web of belief. Coherentist epistemologies bear on two issues posed above. First, explanatory coherence theories of justification (Harman 1973, 1986; Lycan 1988, 2002; Thagard 1989, 1992) provide some of the clearest accounts of how the virtues contribute to explanation.[22] Above, we suggested that de Regt might recoup the intelligibility condition by finding nonexplanatory uses of the virtues, so using these coherentist epistemologies as a foil might prove a useful starting point.

Additionally, coherentist considerations might spare R&D from the problem of irrelevant insights. For instance, if the target of understanding becomes some body of information unified by a common topic, then grasping one bit of information—say that "Streptococcus pneumoniae is a bacterium"—will only amount to understanding something about a more general topic (e.g., bacteria) but not about those curious oil eaters in the Gulf of Mexico.

By developing these ideas, understanding may come to lift itself out of the shadows of explanation. But there is quite a bit of work to be done before the friends of understanding can claim that victory. Until that work is pursued, we should continue to adopt healthy skepticism about the distinctiveness of understanding.

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22. Thagard's (1992, 65–66) Principles of Explanatory Coherence provide the most elegant statement along these lines.

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