Reconstructing Scientific Realism to Rebut the Pessimistic Meta-induction*

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This paper develops a stronger version of 'inference-to-the-best explanation' scientific realism. I argue against three standard assumptions of current realists: (1) realism is confirmed if it provides the best explanation of theories' predictive success; (2) the realist claim that successful theories are always approximately true provides the best explanation of their success; and (3) realists are committed to giving the same sort of truth-based explanation of superseded theories' success that they give to explain our best current theories' success. On the positive side, I argue that (1) the confirmation of realism requires explaining theories' explanatory success, not just their predictive success; (2) in turn this task requires a richer realist model of explanation that brings into the explanans both (a) successful theories' epistemic virtues (e.g., unification and simplicity) and (b) the standards governing these virtues, as well as truth; (3) this richer realist model is further confirmed because it can better explain the success of theories in gaining wide acceptance among scientists; and (4) the model is further supported because it is superior to 'preservative realism' in providing a plausible rebuttal of the pessimistic meta-induction from the many past successful-but-false theories to the likelihood that our best current theories are likewise false.

1. Introduction. For many, the no-miracle argument provides the most compelling defense of scientific realism. Realists argue that realism is vindicated if it can be shown that it constitutes the best explanation of the success of scientific theories, without which success is a miracle. Yet there is no agreement concerning the criterion of success. Realists equivocate between two types of success: (1) predictive success (instrumental reliability, or novel prediction) and (2) explanatory success. On the one hand, some realists argue that positing the approximate truth of successful

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theories is required to explain the fact that they succeed so well in correctly predicting 'novel' kinds of phenomena either (a) different from those they were designed to accommodate or (b) unknown at the point when the theories were first elaborated (Psillos 1999, 105–108). Even among realists who give no special weight to 'novel' predictions, it is still the predictive success of theories that is taken to evoke the need for a realist explanation (Boyd 1981, 1991).

On the other hand, scientific realists typically hold that the best theories possess epistemic virtues such as simplicity, unification, intuitive plausibility, and so forth that enable them to explain many of the observable phenomena that they predict. Indeed the presence of these explanatory virtues in theories is a major component of what makes them better than rivals. Many realists hold that 'inference-to-the-best explanation' is the central methodological standard through which theories are confirmed by their observational implications. Explanatory success is thus central to a theory's confirmation (Psillos 1999, 171). This raises two potential difficulties for realists: (1) Does the confirmation of scientific realism require that it provide the best explanation of theories' explanatory success, or is the explanation of predictive success enough to confirm realism? (2) Does the sort of explanation realists provide for predictive success work for explanatory success? I argue that plausible answers to these two questions motivate significant revisions in the statement of 'inference-to-the-best explanation' (or 'explanationist') scientific realism. I defend specific revisions in both the explananda and explanans of scientific realism. In particular, I argue that in the case of our most successful and well-established current theories, their approximate truth alone is not sufficient to explain their success. A better realist explanation of success requires that we include both (1) current theories' epistemic virtues and (2) their standards of success in the explanans of the explanation. First, I argue that it is better because it is more intuitively plausible than the current version of scientific realism. Second, it is better because it also explains why the scientific community accepts a scientific theory. Third, it is better because it provides scientific realists with a convincing rebuttal of the pessimistic meta-induction. Fourth, it is better because it also yields a better explanation of the failures of scientific theories, as well as their successes. In sum, I will defend my enriched realist explanatory framework as better than the current 'truth-alone' framework on the grounds that it provides a more unifying, complete, and intuitively plausible explanation of a theory's success.

For scientific realists, the presence of such epistemic virtues in a scientific theory (e.g., internal consistency, unification, completeness, intuitive plausibility, etc.) enhances both its explanatory power and thus the extent to which the theory (in this case, scientific realism itself) is well confirmed

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by the evidence it best explains (in this case, the empirical success of scientific theories). Thus, the argument below seeks to establish that the new version of scientific realism developed here is far better confirmed than the current version.

2. Explaining Explanatory Success. Scientific realists ought to be able to explain the explanatory success of a theory—the presence in a theory, not just of predictive power, but the power to explain many observational phenomena. While scientific realists do not need to agree on one single paradigm of explanation (e.g., a casual or unificationist account), they tend to agree on the epistemic virtues that give a theory explanatory power. Realists commonly identify epistemic virtues such as unification, consilience, simplicity, intuitive plausibility, internal consistency, completeness, and empirical adequacy as the markers or criteria of a scientific theory's explanatory power. But why should such 'explanatory virtues' bear on realists' account of scientific knowledge or the empirical success that betokens such knowledge for realists? After all, such epistemic traits of a theory are often referred to as its 'super-empirical virtues'. As such, they are set against its empirical virtues—the quantity, accuracy, or novelty of its predictions. In this vein, the explanatory virtues of a theory can be seen as the embodiment of pragmatic interests, easily explained in psychological or sociological terms, not epistemic ones. The presence of such virtues in a theory would express the practical aims of its designer(s) and not bear on its epistemic status as scientific knowledge. This point of view would justify realists' focus on the explanation of a theory's predictive success alone.

But the larger framework of scientific realism provides good reasons to embrace a notion of empirical success, which ties it to a theory's explanatory success (Doppelt 2005). Consider the way realists seek to rebut a common argument against realism: the argument from the underdetermination of theory by observation. To set the context, suppose that we represent a scientific theory as a hypothetico-deductive system and its empirical success as a function of its true observational implications. This classical model opens the way onto the classical instrumentalist refutation of realism—the underdetermination argument. Scientific theories that make contradictory claims about unobservables can imply all and only the same observational consequences. Given the possibility of observationally equivalent theories, both of which cannot be true, it is unreasonable to take a theory's observational consequences as evidence that the theory is true.

A powerful realist rejoinder takes the underdetermination argument to show that observational equivalence is not evidential equivalence (Psillos 1999, 162–174). The presence of explanatory virtues in one theory and

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their absence in another establish that the former is the only one genuinely confirmed by its observable consequences. The epistemic relation of confirmation cannot be reduced to the logical relation of a theory (with auxiliaries) to its observational implications. Rather, a theory gains confirmation from its observational consequences only if it provides the best explanation of these consequences. Thus in the realists' rebuttal of the underdetermination argument, a theory's explanatory virtues possess fundamental epistemic importance bearing on its confirmation.

Even putting aside their rebuttal of the underdetermination argument, realists have advanced several additional reasons for taking the presence of theoretical virtues in a theory (e.g., coherence with well-established background knowledge, completeness, consilience, simplicity, internal consistency) as evidence bearing on the truth of the theory. McMullin (1987) stresses that explanation, as well as prediction, constitutes a central aim of science and a key trait of a good theory. It is thus rational to accept a theory with these explanatory virtues over those without such virtues, where acceptance implies a belief in the greater likelihood that the theory is true. Boyd (1973, 1981, 1984) emphasizes that a new theory with these explanatory virtues is more plausible to believe than rivals without them because well-established background theories that have proved predictively successful exhibit these same explanatory virtues. Thus the theoretical plausibility and evidential support of the background theories scientists accept carry over to a new theory with similar theoretical virtues. In yet another version of this realist argument, Salmon (1970, 1985, 1990) has maintained that it is reasonable for scientists to ascribe prior probabilities to new theories based on the degree to which they exhibit theoretical virtues exhibited by the most well-confirmed theories in the history of mature sciences.

The point here is that realists have long tied the confirmation of theories to the presence of explanatory virtues. My aim is not to evaluate the reasons advanced by realists for this claim or to provide a new argument on its behalf—though it is a claim I accept. Rather, my argument is simply that if explanatory power is so central to the epistemic credentials of a theory for realists, then the realists' explanation of the success of our best theories is incomplete if it does not explain their explanatory as well as their predictive success. 'Inference-to-the-best-explanation' realists have failed to see this, but their defense of realism can be strengthened when the point is seen and accommodated, as I argue below. For this reason, realists ought not embrace any conception of empirical success that detaches it from the very explanatory success required by confirmation and the status of a theory as knowledge. Thus the presence of explanatory power in a theory will constitute important dimensions of its empirical success that scientific realists will want to explain. Indeed several critics

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of realism embrace this view of empirical success as well (Laudan 1981a; Chang 2003). Put differently, any realist explanatory framework that can provide a unifying account of a theory's explanatory as well as its predictive success will be superior, on the realists' own standards of unification of disparate phenomena and completeness, and thus be better confirmed.

In this essay, I will present several arguments to show why and how the case for scientific realism is strengthened if realists account for the explanatory as well as the predictive success of our best current theories. But at this point, an initial argument can exhibit how limiting the realists' commitment to the approximate truth of theories with the requisite explanatory virtues strengthens the case for realism. Barrett (2002) has argued that the case of quantum physics establishes that it is unreasonable to infer the approximate truth of a theory from its great empirical success. On his account, the standard collapse articulation of quantum physics enjoys a striking success in providing highly accurate statistical predictions and some explanations of otherwise counterintuitive quantum phenomena. The unrivaled predictive power of the theory rightly makes it, together with special relativity, the foundations of physics today. Nonetheless, so he argues, quantum physics, in its present form, cannot be true because it is internally inconsistent and makes contradictory claims concerning the structure of the physical world. Worse yet, the conjunction of quantum mechanics and special relativity cannot be true because the two theories are inconsistent with one another.

In particular, collapse dynamics and deterministic linear dynamics imply contradictory states of the system. The problem might be resolved if quantum physics provided an account of the differences between measuring devices and other physical systems. But lacking such an account, the theory is either logically inconsistent or incomplete. This state of affairs has motivated several alternative formulations of quantum physics with striking differences concerning what the theory is supposed to be asserting concerning the underlying structure of the physical world. And the inconsistency of quantum physics, in its standard and rival interpretations, with special relativity only makes matters worse when it comes to inferring the truth or approximate truth of the theory from its success.

Barrett's (2002) characterization of quantum physics makes a strong case for its spectacular empirical adequacy and instrumental reliability. But it provides no argument at all against scientific realism, as characterized in this essay. On his account, the theory presently lacks the epistemic virtues that would be required to satisfy the standards of explanatory success central to the realists' inference to approximate truth. In particular, his account implies that quantum physics now lacks the internal coherence, intuitive plausibility, and/or the completeness taken by sci-

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entific realists to be central among the criteria of explanatory success (Psillos 1999, 171). The fact that experts cannot agree on what the theory asserts concerning the fundamental structure of the physical world calls into question its intuitive plausibility and intelligibility. Its inconsistency with special relativity powerfully bears on its intuitive plausibility for realists. The realist standard of internal coherence requires the absence of contradictions in the theory. All these problems may be resolved in the future, but the very fact that experts continue to disagree about how to resolve them shows that even their own standards of conceptual coherence and explanatory success have not yet been met by the theory. In this essay, I argue that realists are committed to explaining explanatory success. In addition, I will also argue for a version of scientific realism on which only those current theories that satisfy high standards of both explanatory and predictive success justify the realist inference to their approximate truth. In its present form, quantum theory, impressive and powerful as its predictions are, provides absolutely no counterexample to scientific realism. This consequence of the account of scientific realism defended here is one prima facie argument in its favor. It blocks the very sort of blanket antirealist argument Barrett employs quantum physics to establish.

3. The Truth Alone Explanation. I have argued that realists should be able to explain the explanatory success of scientific theories. This argument raises the question of whether the realist explanation of predictive success works for the case of a theory's explanatory success. I focus on realist explanations of the success of our best current theories, ones we take to be true. In these cases, does the realist explanation of predictive success plausibly extend to explanatory success? Let me begin by underscoring the intuitive plausibility of the realists' explanation of a current theory's predictive success. If we need to explain why a theory such as plate tectonics succeeds in predicting many different natural kinds of phenomena, the realist hypothesis that the theory is approximately true provides a plausible causal explanation. It links the underlying causal mechanism posited by the theory to the production of the various phenomena it correctly predicts.

On the other hand, the same intuitive plausibility is not evident if we employ the realists' hypothesis to explain a current theory's explanatory success. In this case what needs explanation is why our best current theories succeed in exhibiting the relevant explanatory virtues of simplicity, unification, consilience, completeness, intuitive plausibility, and empirical adequacy. The realist answer—because the theories are true—doesn't seem to explain why they are simple, unifying, consilient, plausible, and so forth. The realist is left with the explanatory success of a theory as a miracle, something that the realist cannot explain.

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But by modifying the terms of the realists' explanation, we can get a more plausible statement of the realists' argument. Why does a current theory succeed so well in producing simple, consilient, and unifying explanations of phenomena? Because the truth about nature or, better yet, nature itself possesses the very unity, consilience, simplicity, harmony, and so forth projected by the theory and is thus causally responsible for the success of a theory with precisely these virtues.

This explanation of a current theory's explanatory success is well suited to the realist argument. Unlike instrumentalists and empiricists, realists do not regard the presence of explanatory virtues in a theory as a mere expression of practical or aesthetic interests. On the other hand, some philosophers have regarded the unity and symmetry of nature as a metaphysical, methodological, or regulative principle of scientific inquiry, prior to the concrete results of empirical investigation. Scientific realists will not embrace this view. Rather, once a current theory succeeds to a high degree in realizing stringent standards of simplicity, unification, consilience, and so forth, these standards can be reasonably regarded by scientific realists as well-confirmed empirical hypotheses concerning the structure of nature itself. By this route, we arrive back on familiar realist terrain. It would be a miracle that our best current theories succeed so well in actualizing our highest standards of simplicity, consilience, unification, and so forth were it not the case, or approximately 'true', that nature itself is simple, unified, and symmetric in the ways implied by these theories.

My modest enrichment of the no-miracle argument provides the basis for a realist explanation of a current theory's explanatory success. The realist can explain a theory's predictive success by the hypothesis that it is approximately true and explain its explanatory success by the additional hypothesis that the truth, or nature itself, has the very properties (simplicity, unity, etc.) embodied in the epistemic virtues that give the theory its explanatory power. In any case, I will now argue that even with these modifications, these hypotheses concerning the truth of a theory alone cannot explain its explanatory success. The current realist explanation of theories' predictive success lacks intuitive plausibility as an explanation for theories' explanatory success.

4. Bringing Epistemic Virtues and Standards into the Explanans of Realist Explanation. Consider the realist's standard of intuitive plausibility, on which background knowledge or the structure of other successful current theories favors the explanatory power of one theory over another. To provide a good explanation of a theory's intuitive plausibility, the realist will need a model rich enough to include the wider web of well-entrenched scientific beliefs and the logical, conceptual, or methodological relations

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between it and the theory whose plausibility is at issue. As we saw in the case of quantum physics, its inconsistency with special relativity provides a powerful obstacle to its intuitive plausibility. It is difficult to see how any independent feature of nature, or the truth of a theory, could by itself explain its intuitive plausibility. But realists will want to explain the theory's intuitive plausibility, because that will constitute an important part of the explanation of its explanatory success. Does this involve any equivocation concerning whether the epistemic virtue of intuitive plausibility is functioning as explanans or explanandum? No, because it may function as both in the best realist explanation of a theory's explanatory success or power. Its explanatory success can be explained as (in part) a result of its intuitive plausibility, and in turn, its intuitive plausibility can be explained as the result of its relational properties with respect to the wider background of well-established scientific knowledge. The intuitive plausibility of a theory is part of the explanation of a theory's explanatory power, but it should not function as an 'unexplained explainer' in the explanation because it too can be explained in the manner I have just described.

Similar considerations apply to the explanation of other explanatory virtues of theories. Let us imagine, contrary to fact, that Newtonian mechanics is true and that we seek to provide a realist explanation of its success, in particular, its spectacular success in achieving explanatory unification. Part of the realist explanation, as I argue above, is that nature itself (e.g., the very nature of celestial and terrestrial motion) possesses the unity ascribed to it by Newtonian mechanics. But part of the explanation requires that we show why the theory satisfies the realists' standard of unification so much better than its rivals in mechanics. Unification refers to the power of a theory to provide a single 'unifying' explanation of very different kinds of phenomena that previously require distinct types of explanation. Before Newton, celestial and terrestrial bodies are understood to require essentially different sorts of explanation. Newton's laws unified heaven and earth, raising the standard of unification for physics and surpassing the explanatory unification of other theories at the time. These considerations form an essential part of the explanation of the success of Newtonian mechanics. The explanation remains a realist one just in case the approximate truth of the theory, and the structure of nature it describes, also plays an essential role in the explanation. Empirical success is not just a relation between nature and a theory, but also between the theory and the epistemic virtues and standards (e.g., unification) that enable it to succeed and to be embraced as a success by its exponents and scientific realists. Why does the realist explanation need to bring into the explanans both the epistemic virtue of unification and the operative standard of unification? Isn't the inclusion of both redun-

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dant? Not so, on my argument. While a theoretical virtue such as unification is commonly valued and exhibited by the most successful theories in the scientific tradition, the standards of unification change and indeed become more stringent as theories with greater explanatory and predictive power are developed. So a theory's explanatory success is partly explained by the fact that it possesses the virtue of unification, and in turn the presence of this virtue is explained by the way the theory actualizes the highest standard of unification developed at this point in the scientific tradition. Once again, the epistemic virtue of unification is functioning as both part of the explanans and part of the explananda of the complete realist explanation that I am proposing. The explanatory success of Newtonian mechanics is explained in part by its unifying power, and its unifying power is in turn explained by the way in which it raised and actualized a higher standard of unification than its predecessors and rivals. I now want to argue that my framework for the realist explanation of success is more intuitively plausible than the 'truth-alone' explanation, because the account of empirical success it employs is more plausible.

The "empirical success of a theory" is neither a brute datum nor a value-neutral observation term. It is a value-laden term, relative to certain standards of theory appraisal. Theories do not come equipped with ready-made instructions concerning how their success is to be evaluated. This holds true of predictive success as well as explanatory success. Typically in science, there is some discrepancy between a theory's predictions and the measured values of the observed phenomena. Standards of empirical accuracy are required to determine whether or not the discrepancy is within the acceptable margin of error and, thus, whether or not the predictions succeed or fail (confirm or disconfirm the theory). The 'success' of a theory is a result of both (i) the way the world is and (ii) the way the theory fulfills our highest standards of explanatory and predictive success. The best realist explanation of our best current theory's success will refer to both (1) the approximate truth of what the theory says about nature and (2) the virtues of the theory that enable it to meet our highest standards of explanatory and predictive success. Presumably, point 2 of the explanation of a current theory's success will also explain when and why scientists take the theory to be true and use it as the basis of further research. At the very least, if the enriched realist explanatory framework I propose can explain a theory's success in gaining scientists' acceptance, as well as its explanatory and predictive success, that will also enhance its virtues of unification, completeness, and thus explanatory power over the 'truth-alone' explanation. Realists ought not embrace any explanation of a theory's success that makes it a miracle that scientists just happen to believe and employ successful theories. Thus, an additional advantage of my version of scientific realism is that it may be able to explain a third

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dimension of success in science: a theory's success in gaining adherents (Barnes 2002).

Consider the fate of the theory of continental drift in the twentieth century, and how to explain the point at which it is successful in gaining acceptance by most earth scientists. True scientific hypotheses are not always successful. To the best of our current knowledge, Wegener's assertion of continental drift (his claim that the continents have moved laterally across the earth's surface) was true when he first proposed it in the early decades of the twentieth century (Laudan and Laudan 1996). To be sure, Wegener's hypothesis could explain the wide variety of geological, paleoclimactic, and paleomagnetic phenomena it was designed to explain—for example, the shapes of the continents on both sides of the Atlantic, the existence of quite similar fossil fauna and flora on both sides of the Atlantic at the relevant places in each continent, evidence that the poles have moved, and so forth. Furthermore, its explanatory unification made it a better theory than its rivals. To be sure, certain components of Wegener's theory were false, for example, his hypothesis that the lateral displacement of continents is the result of pole flight and tidal forces. Yet, these false components, by themselves, do not explain why Wegener's continental drift was rejected by most earth scientists at the time. Rather, Wegener's hypothesis did not yet meet earth scientists' standard of consilience or well-confirmed novel predictions/explanations and thus fell short of the requisite predictive and explanatory success expected in the field at the time (Laudan and Laudan 1996).

Thus, if we treat continental drift in its early form as an empirical success, it is hard to explain why a majority of earth scientists rejected it, until 1966–67. We could explain its lack of success with these earth scientists as a result of irrationality, disciplinary bias within subfields, or professional rivalries. But none of these are good explanations in this case. Rather, they rejected drift because the hypothesis so far failed to make any successful (i.e., confirmed) novel predictions and explanations. It did not successfully predict or explain any phenomena unknown and antecedently improbable when the drift theory was first elaborated. In 1966–67, drift theory was elaborated to make two novel and improbable predictions, both of which were then confirmed and explained by drift theory (magnetic reversals and transform faults). These discoveries made it possible for drift theory to realize higher standards of explanatory and predictive success and exhibit greater epistemic virtues than what obtained before. Furthermore, the theory's attainment of this level of empirical success is causally linked to its practical success in gaining the acceptance of the community of earth scientists.

The explanation of its eventual success needs to include an account of how the theory, background knowledge, empirical discoveries, and stan-

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dards of empirical success developed together to the point at which the theory gains the powerful epistemic virtues that made it both (1) the undisputed best explanation in the field and (2) well established by the full range of the standards of rational theory acceptance reasonable to hold at this point. The realist hypothesis that drift theory is approximately true, that nature possesses the unity, consilience, simplicity, and so forth attributed to it by the mature drift theory, is also essential to explain why this theory alone is able to realize the highest standards of empirical success in earth science, given everything else known in the field. Scientific realism is thus secure. But by enriching the realists' explanation to include our best current theories' epistemic virtues and standards of success, we get a much more unifying and complete explanation of their success in gaining adherents and attaining the requisite explanatory power than what we can obtain from the realist hypotheses concerning the approximate truth of theories taken by itself as the sole explanans.

But another key test for this version of scientific realism is its ability to rebut the pessimistic meta-induction. This ability will immeasurably enhance its intuitive plausibility by rendering realism compatible with our background knowledge concerning the historical record of successful-but-false scientific theories.

5. Can Preservative Realism Rebut the Pessimistic Meta-induction? Critics of scientific realism are not likely to be swayed by my argument so far. For any realist explanation of the success of our best current theories seems undone by Laudan's (1981a) litany of successful theories in the history of science, now taken to be false. If we cannot appeal to the approximate truth of these outdated theories to explain their success, how can we reasonably appeal to the approximate truth of our best current theories as part of the best explanation of their success? Moreover, how can realists circumvent the pessimistic meta-induction from 'the many successful-but-false theories' to the likelihood that our most successful current theories are also false and that all theories, no matter how successful, are false?

Explanationist realists try to rebut Laudan's argument by also defending 'preservative realism'. Preservative realism argues that genuinely successful but outdated theories possessed true components that were responsible for and explain their success and that are 'preserved' by our best current theories. Psillos (1999, 104–114, 280–300) has brought these strategies together and reformulated preservative realism to overcome Laudan's challenge. He employs a three-pronged strategy of dividing and conquering the alleged class of successful but false theories that are thought to undermine realism. First, Psillos embraces novel predictions as the sole standard of genuine empirical success, arguing that this de-

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creases the number of superseded theories that were genuinely successful and that realists are bound to explain as approximately true. But, as I argue above, realists typically assume that successful theories possess a whole set of explanatory virtues (unification, consilience, simplicity, etc.) that constitutes their empirical success, along with predictive accuracy and reliability. Why should novel prediction count as the exclusive measure of successful theories? Assume that Psillos is right that LeSage and Hartley's contact-action gravitational ether failed to make novel predictions (Psillos 1999, 105). Arguably, the theory provided a simple, intuitively plausible explanation for a wide range of gravitational phenomena that otherwise could not be accounted for by the Newtonian notion of action-at-a-distance (Laudan 1981b, 118–119). To be sure, the intuitive plausibility of the gravitational ether hypothesis was roundly rejected by Newtonian inductivists who insisted that the ether theorists' 'method of hypothesis' (abduction) and inferences to unobservables lacked any scientific legitimacy. Nonetheless, in the eighteenth and nineteenth centuries, scientists increasingly embraced 'the method of hypothesis' and gained a significant measure of empirical success by positing the existence of various sorts of ethers to provide mechanistic explanations of well-known phenomena of heat, light, the circulation of blood, and so forth—otherwise unavailable to the inductivist school (Laudan 1981b, 112–136). Novel predictions aside, these ether theories exhibited explanatory success based on the then-plausible assumption that only the posit of underlying and unobservable physical mechanisms could yield a unifying account of the observed phenomena at issue. Empirical success in science always involves some such trade-offs between the distinct epistemic virtues achieved by a theory. Thus Psillos's case is less than convincing for eliminating ether theories such as the gravitational ether from Laudan's class of successful theories, now known to be false.

Nonetheless, for the sake of argument let us allow novel predictions to count as one necessary dimension of a theory's empirical success. Psillos recognizes that there remain apparently false theories such as various versions of the caloric theory of heat that yield novel predictions (associated with experimental calorimetric laws) and are thus successful by his standard. On the second prong of his strategy, Psillos limits the realist's commitment to the truth of those and only those components of a theory that are required to derive its novel predictions. In this vein, he argues that the existence and ascribed properties of caloric theory—as the substantial cause of heat phenomena—were not required to derive the calorimetric laws and novel predictions. By this narrowing strategy, the realist can explain superseded theories' success without any commitment to the truth of components of the theory (caloric) totally rejected by subsequent scientific achievements (thermodynamics). Furthermore, the

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true components of a theory (the calorimetric laws) are alone responsible for its novel predictions and are preserved in our best current theories (thermodynamics).

I have argued that realists are committed to explaining the explanatory success of superseded theories. Clearly, there are certain components of a theory necessary for its explanatory power, but not for its novel predictions. For example, the existence of caloric theory and the various properties ascribed to it are essential to the theory's ability to explain many heat phenomena (including the calorimetric laws) that could not otherwise be explained at the time (Chang 2003). Such explanatory components of theories (e.g., caloric, phlogiston, ethers of various kinds) are often the very ones that are false and are discarded, not preserved by our best current theories (Laudan 1981a). Thus Psillos's second narrowing strategy does not circumvent the problem of false but successful components of theories.

Psillos's third strategy is meant to address this problem anew. He recognizes that there remain genuinely successful theories whose success requires the postulation of entities and mechanisms that do not exist, to the best of our knowledge. His example is the ether theory of light propagation, whose empirical success requires the postulation of a luminiferous ether. The ether theory seems to be conceptually and ontologically incommensurable with the theory of the electromagnetic field that replaces it. How can the realist attribute truth to the ether theory, successful though it is, if the theory involves referential failure (there is no luminiferous ether) and its key theoretical entities are abandoned, not preserved by electromagnetic field theory?

Psillos's third strategy seeks to establish sufficient continuity of reference between successful theories to avert the appearance of total referential failure and restore the 'preservative' thesis. He draws on elements of causal and descriptive accounts of reference in order to defend a conception that employs our best current scientific theories to fix the reference of superseded posits such as the luminiferous ether. On this conception, two theoretical terms, L (the luminiferous ether) and E (the electromagnetic field), refer to the same entity (in this case, the electromagnetic field) if and only if two conditions hold. First, there is some overlap in the kind-constitutive causal powers ascribed to L and E, by their respective theories, in virtue of which each of these putative entities is taken to play a causal role in bringing about the effects both theories seek to explain. Second, theorists' acts of reference in referring to L and E are caused by one and the same entity, whose true identity is fixed by our best current theory. In this case it is the electromagnetic field to which ether theorists unwittingly referred. Thus ether theorists embraced the true hypothesis that there is an entity with causal powers sufficient to bring about the phenomena associated

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with the propagation of light, and these true components of ether theory explain its empirical success and are preserved by electromagnetic theory.

For the sake of argument, we may grant that this realist conception of reference can explain the ether theory's success in making novel predictions. But it is implausible to think that it can explain the theory's explanatory success and its acceptance by scientists. To this end, we need to bring in components of the theory that gave it explanatory virtues such as intuitive plausibility, simplicity, unification, consilience, and so forth and motivated ether theorists to embrace it. These components involve theoretical claims about properties of the luminiferous ether, which are false and abandoned, not preserved by our best current theories. Psillos's 'Whiggish' conception of reference provides far too little in the way of true components for the realist to explain the explanatory success and scientists' acceptance of the luminiferous ether. To be sure, Psillos is not concerned with the success of a theory in gaining scientific acceptance, though I have argued that the ability of realists to explain this dimension of success enhances the epistemic virtues of scientific realism. In any case, on the account I propose, the success of a theory in gaining acceptance is typically a result of its explanatory virtues. Psillos can provide no reason for denying that explanatory success is empirical success and is often driven by wholly false components of theories in no way preserved by our best current theories. My conclusion is that Laudan's challenge—theories that are successful but false—will not go away and has not been overcome by the strategies advanced by preservative realists such as Psillos (Doppelt 2005). But is there a way of defending explanationist realism, which parts company with preservative realism?

6. How Realists Can Rebut the Pessimistic Meta-induction. The above critique of preservative realism sets the stage for my two proposals concerning a revision of scientific realism to provide the best explanation of the empirical success of theories. First, I propose that scientific realism can be vindicated if realists confine their realist commitments to the approximate truth of our most successful and well-established current theories, as an essential component in explaining their empirical success. Confining the realists' commitments to the approximate truth of current theories that are both (1) our most successful and (2) well established is not a redundant or trivial stipulation. A powerful current theory may be more successful than its rivals or predecessors in a field, yet still fail to meet some standards of explanatory and predictive success to such an extent that it is not successful enough to be reasonably regarded as well established. For example, a theory may exhibit a high degree of unification and empirical accuracy. Yet it may have limited intuitive plausibility because it is internally inconsistent or inconsistent with other well-estab-

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lished background theories. Indeed, this is precisely how I have characterized quantum theory, as it is described by Barrett (2002). This weakness may be further evidenced in the theory's limited success in gaining wide acceptance or an agreed-on interpretation by experts in the field. So, the most successful current theories are not necessarily well established. Thus my first proposal is that realists rigorously restrict their commitment to the approximate truth of those and only those current theories that are both our most successful and well established. I will refer to current theories as 'our best' only if they are both well established and most successful. A robust scientific realism requires a critical evaluation of our most successful current theories and is not dependent on spreading the mantle of approximate truth as widely as possible over currently successful theories, whether or not they are well established.

Second, I propose that realists explain the success of superseded theories without any commitment to the truth of these theories, or any components of them. These two proposals may be able to defend explanationist realism by separating it from the pitfalls of preservative realism. How? Suppose that the realist can establish that the best explanation of (1) the success of our best current theories shows that their success (the explanandum) and the factors responsible for it (the explanans) are different in kind from (2) the success of superseded theories and the factors responsible for it. In particular, suppose that the best explanation brings the approximate truth of our best current theories into the explanans of point 1 yet can explain point 2 without bringing the approximate truth of the superseded theories into the explanans of their success at all. In that case the best explanation of points 1 and 2 will provide good reason for rejecting any pessimistic induction from the successful-but-false superseded theories to the likelihood that our most successful and well-established current theories are also probably false. If this argument works, it should be very attractive to realists who hold that 'inference-to-the-best explanation' is the heart of scientific confirmation. For, on the argument I will give, 'inference-to-the-best-explanation' realism is worked out to trump the antirealist pessimistic meta-induction. To begin the argument, how can realists explain the success of superseded theories without the hypothesis that they or any theoretical component of them were true?

The realist has ample resources for explaining the success of a superseded theory without the assumption that it was partly true. Return to the case of Newtonian physics. We can explain its explanatory and predictive success (and its success in gaining adherents) in terms of the stunning unification, simplicity, and empirical adequacy exhibited by the theory, in the context of what was then known about the observed world. In addition, realists can also avail themselves of the assumption that our best current theories are true in explaining the success of Newtonian

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physics. Our best current theories (relativity physics) show why Newton's laws work for a more limited set of circumstances than their truth would require. More generally, we can almost always employ our best current theories to explain why superseded, false theories (e.g., Ptolemaic astronomy) worked where they worked, and failed where they failed, without attributing approximate truth to them or any components of them. But does this decoupling of the success of theories from their approximate truth undermine 'inference-to-the-best-explanation' realism? After all, in my proposed reconstruction of realism, the approximate truth of theories is no longer always the best explanation of their empirical success!

The realist need not be committed to preservative realism in order to defend explanationist realism as a commitment to the approximate truth of our best current theories. But my version of this position must confront a question raised by Laudan's challenge to realism. If we can explain (1) the success of superseded theories on the assumption that they were entirely false, why isn't it reasonable to provide the same sort of antirealist explanation of (2) the success of our best current theories? How can the best realist explanation of points 1 and 2 establish any qualitative difference between them concerning their approximate truth?

A plausible realist answer lies in the direction of identifying good reasons for making a qualitative distinction between the success of our best current theories and that of their superseded predecessors. Our best current theories enjoy a singular degree of empirical confirmation impossible for their predecessors, given their ignorance of so many kinds of phenomena and dimensions of nature discovered by our best current theories. Cognitive progress implies the growth of scientific knowledge: the fact that one of the main ways science progresses is by advancing theories that generate new phenomena, unknown to their predecessors, and explaining these phenomena, as well as many phenomena accommodated by their predecessors. But on the present approach, there is more to this process than just the accumulation of ever greater empirical support for the best theories. The process also elevates the very standards of predictive and explanatory success that governs scientific knowledge. The most powerful theories in a field redefine the kinds of unification, consilience, simplicity, empirical accuracy, completeness, internal coherence, and intuitive plausibility that it is possible for theories to achieve and that any successful theory worthy of scientists' acceptance is thereafter expected to achieve. I have argued that the realists' explanation of success ought to include in the explanans the virtues of a theory that enable it to both raise the standards of success and meet them, to some unique and unprecedented degree.

What distinguishes our best current theories from their predecessors is that they alone stand at the pinnacle of this process of raising the standards

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of empirical success. It is this fact that justifies realists in providing a different explanation of the success of our best current theories than they provide to explain the success of their predecessors. How ought realists explain the success of our best current theories? First, their explanation should invoke the presence of certain epistemic virtues in our best current theories that enables them to satisfy the highest standards of success evident in the whole scientific tradition. That is part of the explanation of their success. If we go on to ask why our best current theories alone are able to meet such uniquely high standards and their predecessors are not, the hypothesis that the reason is that the former are approximately true while the latter are false provides a plausible component in a compelling realist explanation.

From this standpoint, the vulnerable link in the pessimistic meta-induction is the treatment of all theories' empirical success as a unitary phenomenon, supportive of an inductive inference. For my brand of realism, the most striking thing about our best current theories is not mere success, or even the fact of more success than predecessors. It is rather the fact that they succeed in both raising and, to an impressive degree, meeting standards of accuracy, unification, consilience, explanatory breadth, completeness, and so forth that are qualitatively far more demanding than all their predecessors either aimed at or attained. Put differently, our best current theories alone meet the standards of confirmation that are the most reasonable criteria of theoretical knowledge in science, given everything else we know today. Of course this fact could change. But unless one is a skeptic, this possibility does not undermine a rational commitment to current standards as the best. Thus, this fact remains a striking one about our best current theories that differentiates them, their success, from that of superseded theories. Realism provides a plausible and perhaps the best explanation of the special position occupied by our most successful current theories. In other words, if we ask why our best current theories are able to actualize the highest, most stringent standards of success and confirmation in the whole scientific tradition, the realist explanans—namely, that it is in part because they are approximately true—is plausible. If we ask why superseded theories, regardless of their success, do not meet such standards, the realist explanans I am proposing—because they were false—is also plausible.

7. The Pessimistic Meta-induction Resurrected. Of course, what I have said about our best current theories (e.g., the special theory of relativity) could be said about Newtonian mechanics in its time, relative to what was then known. But does that eradicate the difference I have characterized of the special feature of our best current theories' success that realism seeks to explain? These considerations may inspire proponents of

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the pessimistic meta-induction to attempt yet another formulation of their antirealist argument to challenge the reconstruction of scientific realism defended here. After all, a powerful argument such as the pessimistic meta-induction can usually be restated in a new form to challenge any novel justification of scientific realism. The pessimist may grant that our best current theories succeed in realizing the highest and most reasonable standards of empirical success evident in the relevant field of scientific inquiry. On the other hand, so did superseded theories, until the standards of empirical success were yet again raised in light of new discoveries and theoretical developments. To the pessimist, this grounds an inductive inference to the claim that in all likelihood, the high standards met by our best current theories will also be superseded by yet higher standards that our best current theories will not be able to meet. And this new version of the pessimistic induction may seem to undermine the inference to the approximate truth of our best current theories that I defend above.

But this new pessimistic inductive argument should not be given a free pass as though it were on a par with the original pessimistic induction from past successful-but-false theories to the likelihood of the falsity of our most successful current theories. It is a very different argument lacking the credibility of Laudan's original argument. Arguably, in the history of the sciences, there is greater continuity in standards of empirical success than in the theories taken to realize them. Furthermore, there are cases in which theories do raise or alter the standards of success and subsequently satisfy these higher standards. So, it is far from clear that the inductive evidence for the likelihood that the high standards met by our best current theories will alter and current theories will be unable to meet them is as strong and convincing as the inductive evidence based on successful-but-false theories. Any new pessimistic meta-induction concerning my defense of realism needs to be separately stated, evaluated, and confirmed, independently of Laudan's original pessimistic induction.

But, for the sake of the argument, imagine that there is inductive evidence that the high standards met to a significant degree by our best current theories will in all likelihood be superseded by yet higher standards that our best current theories will be unable to meet and that yet new theories will be able to meet. Note that this new meta-induction is simultaneously optimistic and pessimistic. It is optimistic about the cognitive progress of science but seems to be pessimistic about the inference to the approximate truth of any theory, regardless of how well it succeeds in realizing the highest known standards of predictive and explanatory success.

Nevertheless, the form of inference-to-the-best-explanation realism I defend here provides a natural and powerful rejoinder to this new mix of pessimistic and optimistic induction concerning the future of science. On

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my argument, scientific realism stands or falls on its ability to provide the best explanation of the fact that (1) our most successful current theories uniquely succeed in meeting the highest and most reasonable standards of scientific knowledge in the whole field and (2) superseded or rival theories lack this success. The hypothesis that our best current theories are approximately true, and superseded or rival ones are false, provides one essential component of a compelling realist explanation of this fact. The force of this realist explanation of an evident fact concerning our best current theories—which needs explaining—is in no measure diminished by what happens in the future concerning the standards or theories in the field. If and when higher standards and more successful theories appear, this development defeats not scientific realism but rather which theories it is reasonable for the realist to take as approximately true. Such a development would simply alter what scientific realism needs to explain, not the realist explanation of what distinguishes the unique success of the best theories that meet the highest standards from their predecessors or rivals.

In this respect, scientific realism is in the same boat as all empirical inquiry. New facts or evidence may always alter what scientists (and realists in the present case) need to explain. But it does not follow that the sort of explanans employed to do the work of explanation is thereby undermined. If and when new higher standards of success develop and realists seek to explain the unique success of new theories in meeting these standards, the realist hypothesis that it is in part because these theories are approximately true remains an entirely reasonable and compelling explanation. Scientific realism need not be committed to the view that we can determine once and for all time which theories it is reasonable to take as approximately true. Rather, the realism defended here is committed to the view that it is reasonable to infer the approximate truth of whichever theories succeed in satisfying the highest standards of predictive and explanatory success in the relevant scientific discipline as a whole. The possibility, or indeed the likelihood, that this will change over time weds scientific realism to an optimistic view of progress in the scientific truths we can know and explain realistically. This epistemological standpoint suffices to circumvent the seduction of any pessimistic meta-induction to the improbability of theoretical truths in scientific inquiry.

Notice that the same strategy of defense is required to defend the constructive empiricist from the pessimistic meta-induction. The constructive empiricist identifies the predictive success of our best current theories with their empirical adequacy. An empiricist could justify the claim that our best current theories are empirically adequate as providing the best or an equally plausible explanation of the fact that they are successful in meeting our highest standards of predictive success (e.g., measures of predictive

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accuracy) and predecessors were not. The pessimistic may argue that superseded theories were predictively successful but proved to be empirically inadequate; therefore, it is likely that our most predictively successful current theories are also empirically inadequate. The constructive empiricist will require the same sort of defense against the pessimistic induction that I have constructed for the scientific realist. Thus, my defense of scientific realism against the new form of pessimistic induction I have sketched gains support if it is the case that even the less demanding position of constructive empiricism is equally in need of a similar strategy of defense against this form of pessimistic induction. Of course, my version of scientific realism holds that explanatory success, not mere predictive success, is a goal and standard central to scientific theories and their empirical success. And it is for this reason that the best explanation of our best current theories' unique overall empirical success (including their explanatory power) requires the realist hypothesis that they are approximately true, and not just empirically adequate.

In any case, to restate the basic argument of this section, the pessimistic/optimistic induction to the likelihood of a scientific future of yet higher standards does not diminish the realist explanation of an evident fact about current science that needs explaining: namely, why and how our best current theories uniquely realize the highest and most reasonable standards of confirmation known to us in the relevant field of inquiry.

8. Failure Explained. The realist case can be further strengthened if we include the failure or shortfalls of theories in what realism seeks to explain, its explananda. Of course, every theory, including the best current theories, is a mix of success and failure. But the realist's explanation of our best current theories' failures need not be the same as it is for superseded theories. The best (realist) explanation of the failure(s) or shortfalls of superseded theories is that (1) they were false and (2) they embraced standards of success that were misguided, impoverished, unrealizable, or overly restrictive in light of subsequent developments and current knowledge. When it comes to the explanation of our best current theories' failures, realists can reasonably provide a quite different account: they can be explained as shortfalls that either will be converted to successes with further scientific inquiry or will be found to lie outside the scope of the current theory in question. This realist explanation of our best current theories' failures is reasonable because the truth or approximate truth of these theories is part of the best explanation of their unprecedented success in meeting the highest, most demanding standards of accuracy, unification, consilience, and so forth in the whole tradition of scientific inquiry, in these theories' respective domains. It is thus reasonable for the realist to account for these theories' predictive or explanatory failure, not as dis-

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confirming or falsifying evidence, but rather as puzzles that will eventually be resolved. This suffices to show that our best current theories (e.g., the special theory of relativity) differ in crucial epistemic respects from their superseded predecessors, blocking an inductive inference from past 'successful but false' theories to the likelihood that our best current theories are also 'successful but false'. In this way, the realist strategy I am proposing employs inference-to-the-best-explanation to trump Laudan's pessimistic meta-induction. If, as I have argued, the realist can plausibly explain (a) the success (and failure) of our best current theories in a way that provides a sharp demarcation between them and (b) superseded theories (and their respective successes and failures), then it is unreasonable to inductively generalize from the falsity of point b to the likely falsity of point a.

In sum, I have defended a reconstruction of inference-to-the-best-explanation scientific realism that revises both (1) what realism seeks to explain (its explananda) and (2) what realism invokes to do the explaining (its explanans). Concerning point 1, I have argued that realists should seek to explain not just (a) the predictive success of theories, but also (b) their explanatory success, (c) their success in gaining scientific acceptance, and (d) their failures as well as their successes. The epistemic virtues of this enriched realist explanation are as follows. A realist explanation that encompasses points a–d evidently exhibits greater unification, consilience, explanatory breadth, and completeness than one that can explain only point a. This makes the enriched realist explanation superior, on the realists' own account of explanatory virtues. I have also argued that this enriched realism is more intuitively plausible than the standard model, confined to the explanation of point a alone. A realist explanation that can explain point b—theories' explanatory success—is much more consistent with realists' account of confirmation as 'inference-to-the-best explanation'—which they employ to defeat the underdetermination argument against scientific realism.

Concerning point 2 above—what realists should invoke to do the explaining of success (the explanans)—I have argued that the best realist explanation of points a–d will include all of the following in the explanans: accounts of successful theories' epistemic virtues; the standards governing the realization of these virtues; the properties of particular theories that enable them to meet or indeed raise the standards and embody the appropriate epistemic virtues; and last but not least, in the case of our most successful and well-established current theories (but not superseded theories), the crucial realist hypothesis that these best current theories are approximately true, which is a key part of the explanation of why they alone are able to meet the highest standards of success evident in the whole of scientific inquiry in the relevant domain.

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In effect, I have argued that this enrichment of the realists' explanans provides a more intuitively plausible version of scientific realism. It is more intuitively plausible because it provides a way for realists to overcome the pessimistic meta-induction (a requirement for any defensible realism) without embracing the implausible elements of preservative realism (Psillos et al.). By expanding the realists' explanans to include the role of epistemic virtues and higher or lower standards of success, the realist gains a plausible way to distinguish the success of our best current theories (and its explanation) from that of their superseded predecessors (and its explanation). In this way, realists can secure the possibility of genuine scientific knowledge and the approximate truth of our best current theories without getting stuck in the implausible morass of needing to attribute approximate truth to superseded theories that are false to the best of our knowledge. For all the above reasons, the enriched version of scientific realism I defend exhibits greater explanatory virtues of unification, completeness, empirical adequacy, and intuitive plausibility than the standard 'no-miracles' realism—the very epistemic virtues at the heart of confirmation for realists. If this is indeed the case, the enriched version of scientific realism advanced here is far better confirmed than the standard 'no-miracles' version of current realism. Finally, this defense of scientific realism happily incorporates the realists' distinctive view of scientific inference—as 'inference-to-the-best-explanation' confirmation—in order to rebut the skeptic's pessimistic inductive inference. Scientific realism is thus confirmed to the extent that it can establish that the most reasonable explanation of our best current theories' success includes the assumption that they are approximately true and rejects any such assumption for the explanation of superseded theories' success. This brand of scientific realism provides a good scientific reason against the acceptance of any inductive inference from the set of past false-but-successful theories to the likelihood that our best current theories are also false. Such a strategy offers the best prospects for the confirmation of a scientific realism concerning our best current theories.

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