

Explaining the Success of a Scientific Theory

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Scientific realists have claimed that the posit that our theories are (approximately) true provides the best or the only explanation for their success. In response, I revive two nonrealist explanations. I show that realists, in discarding them, have either misconstrued the phenomena to be explained or mischaracterized the relationship between these explanations and their own. I contend nonetheless that these nonrealist competitors, as well as their realist counterparts, should be rejected; for none of them succeed in explaining a significant list of successes. I propose a related nonrealist explanation of success that appears to be the most suitable among those considered.

1. Introduction. Arguing for scientific realism, Hilary Putnam (1975) tells us that the success of science would be a miracle were our theories not at least (approximately) true. This basic argument, known as “the no-miracles argument” (a.k.a., “the success argument,” “the miracle argument,” and “the ultimate argument”), is advocated by most scientific realists. Bas van Fraassen (1980), a nonrealist, responds that we need appeal neither to miracles nor (approximate) truth: In essence, we have successful theories because we reject those that are not successful. Realists, however, note a weakness in this nonrealist explanation. While it may explain why, in general, we have successful theories, we cannot explain a particular theory’s success by noting that it has survived our demand that it be successful.¹

The question then becomes, why is T in particular successful? Changing the explanandum to the success of T, rather than science in general, allows

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1. This has been noted by Musgrave (1985, 1988), Lipton (1993, 1994), and Lepplin (1997). The first to recognize this was van Fraassen himself (1980, 40, footnote 34).

the realist to appeal to truth simpliciter rather than approximate truth (as do Kukla, Musgrave, and others). Realists tend to characterize the no-miracles argument as an abductive inference, drawing on Peirce. Peirce construes abductive reasoning in the following way. We begin with a “surprising” observation, (Q). A state of affairs is postulated, and that postulate, (P), would render (Q) “a matter of course.” We conclude that “we have reason to suspect” that (P) obtains (Peirce 1958, 189). Stating the no-miracles argument abductively, we have (something like) the following argument (Lyons and Clarke 2002, xii):

- 1: T is successful, (Q)
- 2: If T were true, (P), then T’s success, (Q), would be a matter of course
- 3: The relationship expressed in (2) shows that the truth of T, (P), provides an explanation of T’s success, (Q)
- 4: In fact, the truth of T, (P), provides a good explanation of T’s success, (Q)
- 5: To say that success, (Q), occurs due to a miracle is to provide no explanation at all
- 6: Aside from the truth of T, (P), there is no other explanation available for T’s success, (Q)
- 7: Therefore, we are justified in believing that T is true, (P)

While premises would likely be added, this captures the basic idea of the no-miracles argument.

2. Competition: Empirical Adequacy. Against premise 6, we can introduce a nonrealist explanation: T is successful because T is empirically adequate. For a theory to be empirically adequate, all of its claims about observables must be true. Though “empirical adequacy” is a term employed by van Fraassen, he does not explicitly advocate it as an alternative explanation for a theory’s success. Nonetheless, it is well worth considering as a competitor. (Hereafter I will use “EA” to denote “empirically adequate” as well as “empirical adequacy.” And I will refer to the explanation on offer as “the empiricist explanation.”)

It may be thought that “T is EA” will not explain T’s success on the grounds that attributing the property EA to a theory merely, “restates its explanandum,” as Leplin puts it (1987, 522).² However, “T is successful” and “T is EA” are distinct assertions. First, a theory whose predictions about observables are all true can nonetheless fail to be successful: For instance, the corollary observation statements may be significantly false. Second, while EA is truth about observables, success pertains to the

2. “T is EA” is one version of what Leplin calls “surrealism”; I will reserve that name for the other version, to be discussed below.

confirmation of a theory's predictions; and false predictions can be confirmed (for example, by false data statements or true but imprecise data statements). Third, "T is EA" says that the theory is true about, not only (a) those empirical predictions that have been observed, but also (b) those that will be, but have not yet been, observed, and (c) those that will never be observed. "T is successful" says nothing about (b) or (c). Clearly, "T is EA" is not at all reducible to, does not redescribe, success. Leplin roughly grants this conclusion more recently, noting that EA "is not identifiable with any achievable record of specific successes, however large" (1997, 22).

Nor does "T is EA" merely constitute a generalization of those predictions that have been successful. As André Kukla points out, "if some previously unexamined empirical hypothesis E is found to be a consequence of T," then "T is EA" includes the claim that E is true (1998, 22). And E is no part of the success being explained. "T is EA" is neither a reiteration nor a mere generalization of the explanandum, and it cannot be faulted as nonexplanatory on such grounds.

Clarifying the explanandum further, we can note that "T is EA" is not being put forward to account for the phenomena the theory predicts. The sense of awe appealed to in the no-miracles argument is surely not about physical phenomena in the world. This can be illustrated by considering the realist's use of approximate truth. Newton's theory may explain why the planets are where they are. But saying "Newton's theory is approximately true" does nothing to explain the planetary positions themselves—even if that claim could explain why Newton's theory makes successful predictions about those positions. "T is EA" is put forward to explain why T's instances have been confirmed when tested (i.e., why T is successful). It is not put forward to explain the specific class of physical phenomena that are entailed in T. We cannot then reject "T is EA" on the grounds that it is unable to explain a theory's consequences. To do so would be to put that explanation into the wrong battle. (The points here will be especially relevant in Section 4, regarding Musgrave's critique of another nonrealist contender.)

Peter Lipton asks, "How does the correctness of unchecked predictions help to explain the correctness of those that have been checked?" (1994, 99). I've just noted that the explanandum of concern is not T's consequences. Nor, however, is it "T's ability to make true predictions." Success is not to be equated even with making (some) true predictions. This is evident given two points noted above, and adding a third. First, "T is EA," does not directly entail that T will be successful: T can fail to be successful due to false observation statements. Second, T's success does not even imply that T's *confirmed* predictions about observables are true. T can be successful despite the falsity of its confirmed predictions: We can have

false observation statements, or, more commonly perhaps, we can possess observation statements that are too imprecise to make the falsity of our theory's precise predictions apparent. Third, success, especially as it is being employed by the realist, is such that we must be able to attribute it to a theory at a particular time. Success cannot then be contingent on what future theories deem to be true claims about observables: Newton's success cannot be contingent on what Einstein's theory deems to be the truth about observables; Einstein's success cannot be contingent on the claims of a future theory, etc. If we had to wait for future theories to tell us when a given theory is successful, we could never witness the phenomenon from which realists infer realism; thus we could never be realists. The explanandum of concern in the realist debate is "T is successful," and this is distinct even from "T makes some true predictions about observables." Because Lipton's comment does not properly capture the explanatory relation, it does not reveal any genuine oddity in the empiricist explanation.

One might suspect that the unacceptability of the empiricist explanation lies in its form. However, while the phenomenon being explained by "T is EA" is distinct from that being explained by a scientific theory, "T is EA" appears to share the form of many scientific explanations: X does Y because X is Z. One scientific explanation that takes this form: Light creates interference effects (X does Y) because light is a wave . . . (X is Z). This acceptable explanation has the same basic form as the empiricist explanation for success: The theory of light predicts confirmed interference effects (X does Y) because the theory of light is empirically adequate (X is Z). In each of these cases X's behavior, doing Y, is explained by a purported property of X, namely, being Z.

Even granting that "T is EA" is to an extent explanatory, realists will assert that it is not sufficiently so. The realist will claim that the nonrealist explanation simply pushes the question back further, and she will ask, What is the underlying reason why the theory makes only correct empirical predictions? Musgrave writes, "One wonders how the empirical adequacy of a theory might be explained if not by postulating its truth" (1988, 242).

3. Truth, Empirical Adequacy, and Success. The claim that "T is True explains T is EA" rests on a set of assumptions about the relationship between these two properties. I will now attempt to make salient a number of misconceptions about this relationship. I will begin to do so by assessing the degree to which each of these explanations implies that which it is purported to explain, success. For lack of a better word, this explanatory property—the degree to which an explanans implies its explanandum—can be deemed an explanation's *degree of implication*.

It is often assumed (or treated as obvious) that the truth of a theory implies its success. In fact, this claim (or something very close to it) con-

stitutes the central and explanatory premise (2, above) of the realist's abduction. However, a number of points make clear that this assumption/premise is false.³ (1) The stipulation "T is true" in itself entails no restriction that any auxiliaries are conjoined to T; the true theory therefore need not lead to any empirical predictions. (We remain mindful here that, generally, in order for a broad range of predictions to be derived from a theory at all, a theory must be conjoined to an enormous number of auxiliary claims.) (2) Even if auxiliaries are conjoined to the true theory, nothing in "T is true" automatically restricts what those auxiliaries say. The auxiliaries thus may afford no empirical predictions whatsoever. (3) Even if the true theory does bring about empirical predictions, it need not necessarily bring about empirical predictions that have been or can be tested given current technology. (4) And with the mere stipulation that T is true, no terribly implausible or obviously false statements are prohibited as auxiliaries; thus it need not be the case that T's testable empirical predictions will be confirmed as true. All combinations of all possible auxiliaries must be considered in determining the likelihood of predictive success coming from a true theory. Given that there is an indefinitely high number of auxiliary hypotheses that could in principle be conjoined to T, there is an indefinitely high number of false auxiliaries and combinations that would render T unsuccessful, despite its truth. Because there is a limit to those combinations of auxiliaries that would engender empirical success, the quantity of possible auxiliary combinations that would bring about predictive success is far lower than the quantity that would fail to bring about such success. It is far more likely that a true theory would be unsuccessful than successful. (5) And even if our auxiliaries bring about true predictions, our observation statements need not be in accord with them, thus rendering predictions nonconfirmed. It appears that the mere fact that T is true does not make "success a matter of course"; T's truth does not even make it *likely* that T will succeed empirically.⁴

As hinted above, the degree of implication enjoyed by empirical adequacy in regard to success is actually greater than any such degree of implication that might be enjoyed by truth. If any auxiliary statements were to "throw

3. Larry Laudan (1981) points out that realists have not shown that the approximate truth of T would entail its success. My conclusion here will be stronger in three senses (indicated by italics): *we have reason to doubt that*, the mere stipulation that T is *true* will even render success *likely*.

4. One might object as follows: perhaps this would be the situation if *any* auxiliary claims were permitted into our theory complex; but, in practice, scientists will only allow theories and auxiliaries that succeed empirically. In raising this objection, however, the realist has lost sight of her goal. The realist seeks to explain success. Saying "our theories are, not only true, they are also successful" will do nothing to *explain* success. Truth would be parasitic on what it is put forward to explain.

off” the observable predictions derived from a given theory in such a way as to render those predictions false, that theory would simply not be EA. (And, I would add that an EA theory must make claims about the observable world.)⁵ Thus, with EA, (1), (2), and (4) appear to be eliminated from the start. “T is EA” implies success to a far greater degree than “T is true.”

Some interesting consequences follow. First, it is assumed throughout the realist debate that “T is true” entails “T is EA.” For instance, Lipton writes, “since empirical adequacy follows from truth (though not conversely) anyone who infers that the theory is true will also infer that it is empirically adequate” (1994, 98). However, recognizing that “T is EA” implies success to a greater degree than does “T is true,” we see that “T is true” cannot entail “T is EA.” In fact, contrary to the suppositions maintained in the literature, the two claims are completely distinct. Neither follows from the other. Second, since a theory about unobservables need not, by itself, tell us anything about the observable world, additional statements must be conjoined to T in order for it to be EA.⁶ “T is EA” then makes a claim about T *as conjoined to other statements*. Third, “T is EA” entails very significant claims *about those statements* to which the theory is connected. It includes the assertion that they are not such that, when conjoined to the theory, they lead to false claims about observables. (While the truth value of a theory cannot, for a realist, be contingent on what we do with the theory—for example, what auxiliaries we connect it to—its empirical adequacy can be and is so contingent.) Finally, since truth makes neither success nor EA likely, adding “T is true” does not obviously strengthen the force of our explanatory package.

4. Competition: Strong Surrealism. Let us ask, nevertheless, can the nonrealist put forward a deeper explanation, one which actually makes reference to theoretical entities and deep-level structures in the world? We might say T is successful because the world is “as if” T is true. (Given the points made above, the informal expression here should be revised to “The world is as if T and all its auxiliaries were true.”) Without explicitly committing himself to it, Arthur Fine (1986) introduces such an explanation as a contender against the realist explanation. Leplin (1987, 1997) brands the position that we only need an “as if” explanation, “surrealism”—to specify that it is a surrogate for realism.⁷ Focusing on the theory’s properties,

5. Of course, this involves refusing to take EA to mean something it was never intended to mean, as vacuously applying to theories that say nothing about observables.

6. See the above footnote.

7. Kukla (1998) divides Leplin’s construal of surrealism into a weak and a strong version, the weak version being what we’ve considered above, “T is EA.” I am reserving the term only for the strong version.

the surrealist explanation of success can be unpacked as follows: The mechanisms postulated by T would, if actual, bring about the same observable phenomena as those that are brought about by actual mechanisms in the world.

“T is EA” makes no claim regarding how the world behaves below the observable level, or even that there is a deeper level. By contrast, the surrealist account refers to a relationship between the unobservable entities postulated in the theory and the unobservable entities of the world. While it avoids equating the two or saying they are very similar, it makes a causal claim that both of these would lead to the same observable situations. The surrealist explanation thus goes deeper than “T is EA.” In fact, in contrast with “T is true,” it appears that strong surrealism would be capable of explaining why a theory is empirically adequate: T is EA because the mechanisms in the theory “keep all the disparate empirical consequences of T in line” (Kukla 1998, 23), and the mechanisms in the world do the same for the corollary phenomena.

An argument Leplin (1997, 27) puts forward against surrealism is that it “presupposes the realist explanation. . . . *Such explanation as [surrealism] does provide is actually parasitic on realist explanation [sic].*” To explain the fact that science is successful, surrealism rests on the claim that truth will lead to success. For surrealism to be an explanation at all, “we are supposed to assume that experience will bear out the theory’s predictions.” “Surrealism must presuppose that theoretical truth will be manifested in experience. But that presupposition is precisely the explanation realism gives of success.” Leplin says it is not only that surrealism requires that realism itself be explanatory, but “the particular explanation realism gives is actually embodied, by implication, in surrealism’s explanation.” He concludes that “there is no distinctive middle position to be staked out, and surrealism shifts, under analysis, into its opposition” (1997, 27).

Leplin is saying that surrealism collapses into realism. However, we’ve just seen that it is not the case that T must be empirically successful if true. Nor does surrealism presuppose that this is the case. At most, surrealism presupposes that T will be successful when T and all of its auxiliaries are true. Moreover, surrealism only presupposes that this strong realist posit offers a potential explanation of success, not that that posit is correct. Doing so, surrealism does not invoke all the properties of the realist explanation. It simply does not claim that the theoretical posits are the same as the structures of the world. The only similarity need be that those posits and the world’s structures would bring about the same phenomena. No matter how we cut it, surrealism is less demanding than realism. So, while surrealism may share, and thus in some way presuppose some of realism’s explanatory strengths, surrealism cannot be “the very explanation realism gives” (1997, 28).

Alan Musgrave expresses a sentiment similar to Leplin's. He interprets surrealism in two ways. Either it is meant as EA; or it is "meant to entail everything that T entails *except* just for T itself." He writes that the latter interpretation "is not a coherent position" (1988, 244). I've emphasized above, that the explanandum at issue is not the class of observable phenomena predicted by T but the success of T. That point applies here. Surrealism does not entail what T entails. It entails that T has a certain property—namely, the property of containing mechanisms that would bring about the observable phenomena. The incoherent position Musgrave is pointing to is not the position of the surrealist. (Nor, as we've noted, is surrealism identical to EA.)

5. The Meta-Modus Tollens. While I've defended the empiricist and surrealist explanations, none of the explanations is suited to explain the success of scientific theories across the board. The history of science is wrought with theories that are successful but not true. A short list can be found in Laudan (1981). While this list has a number of implications for realism, here we need only note that "T is true" cannot explain, let alone stand as the best explanation for, the success of these theories. The same holds, however, for our nonrealist explanations. Despite the modesty of the term "adequacy," empirical adequacy is nothing other than empirical perfection. But, despite their success, the theories on Laudan's list are not, by present lights, empirically perfect. Likewise, the phenomena that would be produced by their mechanisms diverge from the phenomena that have been observed. Neither truth, empirical adequacy, nor surrealism will explain the success of the theories on Laudan's list.

In response to Laudan's historical argument, realists have changed their explanandum from general predictive success to novel success. Notably, the modification of the explanandum to novel success—even when understood in its strictest sense of temporal novelty—does not in itself preclude "T is EA" as an explanation. "T is EA" asserts that all of T's claims about observables are correct, including those never checked. In the debate on scientific realism, little mention seems to be made of the fact that this means EA will bring about confirmed novel predictions, to no less a degree than truth. The same point holds for surrealism.

Given that realists have redefined success as novel success, it might appear that we have salvaged our three contenders as explanations for success. However, I've shown elsewhere (2002) that, contrary to the views of most realists, there have been numerous examples of novel success from theories that are clearly false by present lights. Included in this list are the following: caloric theory, phlogiston theory, W. J. M. Rankine's nineteenth-century vortex theory, Newtonian mechanics, Fermat's principle of least time, Fresnel's wave theory of light and theory of the optical ether,

Maxwell's ether theory, Dalton's atomic theory, Kekulé's theory of the benzene molecule, Mendeleev's periodic law, Bohr's 1913 theory of the atom, Dirac's relativistic wave equation, and the original (pre-inflationary) big bang theory. Each of these theories has attained temporally novel predictive success. And, by present lights, not one of them can be true, empirically adequate, or such that its mechanisms would bring about exactly the (relevant) phenomena observed.⁸ Hence, none of the explanations that we've focused on here will explain the novel success of these theories.

6. Approximate Truth. The realist's natural response would be to say the approximate truth of T provides the best explanation of its novel success. While my focus has been "T is true," and I have addressed approximate truth in this regard elsewhere (2002), I will make a few brief points on the matter here. We've seen above that a true theory need not be successful, and the same points apply no less to approximate truth. In fact, changing the explanans to approximate truth, the situation is considerably worse. A theory that is approximately true, even when it is connected only to true auxiliaries, need not be successful.

Consider, for instance, an indefinitely high number of theory complexes, all of which are identical to the corpus of successful contemporary science, CS. Divide this set of complexes into four subsets, ss1-ss4. Raise the postulated charge of the electron, e , in each of the complexes in ss1. Assign the e in one complex a value that is one one-thousandth higher than e in CS. Assign the e in another complex a value that is one one-billion-billionth higher than e in CS. For each of the indefinitely many remaining complexes of ss1, assign a distinct value to e that falls between these values. In the complexes of ss2, lower e following the same procedure. In the ss3 and ss4, do as with ss1 and ss2 except change the postulated charge, not of the electron, but the proton. Our full set of complexes now consists of indefinitely many complexes that approximate CS. However, each predicts that matter repels matter, thus that no universe exists at all.⁹ Each approximating complex will be a dramatic empirical failure. The point: a slight change in claims about unobservables can lead to entirely different empirical predictions. Theories that approximate one another at the sub-

8. Seeking to address my earlier concern attempting to render success likely the realist may have been tempted to strengthen her explanation to "T and its auxiliaries are true." However, in this section we see the futility of such a move: the quantity of counter instances successful theories that could not have this property, thus those the realist could not explain would increase dramatically.

9. The consequence of changing the charges is discussed in, for instance, Greenstein (1988, 61-65).

empirical level need not approximate one another empirically, and this is so while keeping all auxiliaries and all background theories constant. The situation is compounded exponentially once we allow that a theory's many auxiliaries are only approximately true. Given these additional problems, the stipulation that a theory is approximately true is considerably less likely to imply its success than the stipulation that it is true.

Now this is so even if we demand that approximate truth requires reference. Letting go of that demand, the class of theories and complexes qualifying as approximately true would inflate by the multitudes. And the likelihood that an approximately true theory would succeed would be even more dramatically decreased. Including a nonreferential notion of approximate truth in the second premise of the realist's abductive argument threatens to render that premise altogether untenable. This appears to put a restriction on our notion of approximate truth: an approximately true theory must refer (and, it would seem, must do so in a rather substantial sense).

Accepting this restriction on approximate truth, and looking at our earlier list, we have a number of theories that have enjoyed novel success, but which could not have been approximately true. For they contain central terms—such as “phlogiston,” “caloric,” “atomic vortices”—that do not, by present lights, refer. Therefore, despite the move to approximate truth, it looks as though we have a number of theories whose novel success realism cannot explain (for further details, see Lyons 2002).

7. Competition: Modest Surrealism. How might we explain the success of theories that cannot be true, approximately true, or even empirically adequate? I would suggest we would appeal to a modest version of surrealism (“the world is almost as if T and its auxiliaries are true”).

Modest Surrealism (MS): The mechanisms postulated by the theory and its auxiliaries would, if actual, bring about all relevant phenomena thus far observed and some yet to be observed at time *t*; and these phenomena are brought about by actual mechanisms in the world.

MS shares the explanatory depth of strong surrealism noted above. While it does not strictly entail success, MS—like empirical adequacy and strong surrealism, and in contrast with approximate truth and truth—renders success very likely. For the mechanisms of an MS theory must bring about the same confirmed phenomena as those brought about by underlying ontological structures. Since the above realist explanations fail to make the success of a theory likely, those explanations cannot make MS likely. (The postulates of an approximately true theory need not bring about any of those phenomena that are actually brought about by mechanisms in the world.) So, invoking “T is (approximately) true” to

explain MS would appear to bring no additional impact to our explanatory picture. Further, since there are no successful theories on the list that cannot also be MS, in contrast with the other explanations considered, MS is not precluded from explaining these successes. No other explanation we've considered has such potential breadth.¹⁰ And because the realist explanations considered here cannot explain the success of the theories on the list, they cannot explain why those theories are MS. We cannot then look to the above forms of realism in quest of a deeper explanation of the successes on our list.¹¹ On these grounds, it appears that, if we do wish to follow the realist demand for explaining the success of scientific theories, among the choices here considered, modest surrealism constitutes the better contender.

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10. Granted, MS's compatibility with the list is partly due to the fact that it lacks specificity in terms of when and where our theory's fit with the phenomena will stop. Though this vagueness may constitute a weakness, it is one shared with the realist competitor, approximate truth.

11. While I think there is a possibility of enriching MS (within the confines of the concerns noted), this enrichment will not invoke the truth or approximate truth of T.