Theory Status, Inductive Realism, and Approximate Truth: No Miracles, No Charades

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The concept of approximate truth plays a prominent role in most versions of scientific realism. However, adequately conceptualizing 'approximate truth' has proved challenging. This article argues that the goal of articulating the concept of approximate truth can be advanced by first investigating the processes by which science accords theories the status of accepted or rejected. Accordingly, this article uses a path diagram model as a visual heuristic for the purpose of showing the processes in science that are involved in determining a theory's status. This 'inductive realist' model of theory status then serves as a starting point for explicating an inductive realist view of approximate truth that, it is argued, can explain instances of the success of science, but does not (1) require science's theories to be strictly true in any world or (2) require a metric for measuring how close an approximately true theory is to some strictly true theory. To show the advantages of the inductive realist approach to approximate truth, an example of a major success story of science, the successful eradication of smallpox, is reviewed and then explained.

1. Introduction

Ever since Popper’s (1963) verisimilitude project and the subsequent articulation of the 'no miracles' argument, the concept of approximate truth has played a prominent role in most versions of scientific realism. Consider the claim of the 'no miracles' argument. The basic argument, which traces to Smart's (1963, 39) view that instrumentalists 'must believe in cosmic coincidence', was famously and pithily put by Putnam (1975, 75): 'Realism is the only philosophy that does not make the success of science a miracle.' Realism's explanation of the success of science relies on approximate truth:

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'If scientific theories weren't (approximately) true, it would be miraculous that they yield such accurate observational predictions' (Boyd 1984, 43). Maintaining that 'accurate predictions are no cosmic accident' (Mikkelson 2006, 441), realists argue that 'the best explanation of the instrumental reliability of scientific methodology is that background theories are relevantly approximately true' (Psillos 1999, 80). Indeed, 'realists stress that there is some kind of justification for the belief that theoretical assertions are true (or near true)' (Psillos 2000a, 58). However, adequately conceptualizing 'approximate truth' has proved difficult. Recent efforts have required that statements that are approximately true in this world must be 'strictly' true in some other world (Psillos 1999).

This article's objective is to develop a realist conceptualization of 'approximate truth' that, I shall argue, can explain instances of the success of science, but has the advantage that it does not (1) require science's theories to be strictly true in any world or (2) require a metric for measuring how close an approximately true theory is to some strictly true theory. As background for my approach, I begin by providing a brief review of the problems associated with previous efforts to (a) develop an antirealist explanation of the success of science and (b) articulate a realist conceptualization of 'approximate truth'.

2. Background

An important part of the 'no miracles' argument is that realism is proffered as the best, if not the only, viable explanation for the success of science. Indeed, alternative explanations of the success of science have fared poorly. For example, consider van Fraassen's (1980) argument that the empirical adequacy of a theory may be used to explain the theory's success. Musgrave (1988) shows that explaining the success of a theory by its empirical adequacy is, essentially, the same as explaining true, observational consequences by noting that all the theory's observational consequences are, indeed, true. That is, it is much 'like explaining why some crows are black by saying that they all are' (Musgrave 1988, 242). Also, van Fraassen's (1980) supposed Darwinian explanation of the success of science has been argued by Kitcher (1993) and Psillos (1999) to be an inadequate, phenotype, non-substantive form of Darwinian explanation. And Psillos (2000a, 74) concludes that 'sophisticated agnostic empiricism is not as rational an attitude to science and its practice as scientific realism'. Likewise, Fine's (1986) supposed, anti-realist explanation that theories are successful because the world is constructed as if science's theories were true is not a viable anti-realist explanation because it relies on the claim that truth will lead to success. Indeed, Leplin (1987, 27) concludes that Fine's approach 'presupposes the realist explanation, ... [and] is actually parasitic' on it.

As yet another example of an argument that fares poorly as an anti-realist explanation of science's success, consider that of Stanford (2000). He proposes that a theory, say, $T_1$, is successful because of its predictive similarity to another, unknown, theory, $T$, which is the 'true theoretical account of the relevant domain' (Stanford 2000, 275). Psillos (2001, 347) points out that, among its other problems,
Stanford’s purportedly anti-realist explanation of science’s success, because it relies on the supposed truth of some theory \( T \), actually falls within the scope of the realist explanation. Also, the predictive similarity of \( T_1 \) to the unknown, true theory, \( T \), might be because \( T_1 \) is an approximately true version of \( T \). Therefore, once again, the ‘realist story—and the “no miracle” argument in particular—withstands yet more pressure’ (Psillos 2001, 355).

The problems associated with proposed anti-realist explanations of the success of science notwithstanding, no one disputes that problems remain concerning using approximate truth to explain the success of science. Critics of realism, as well as many realists, themselves, maintain that no coherent articulation exists as to what it would mean for a statement, hypothesis, or theory to be approximately true. For example, the realist Niiniluoto (1980, 446) states, ‘No one has been able to say what it would mean to be “closer to the truth”, let alone offer criteria to determine such proximity’. Likewise, the anti-realist Barrett (2003, 1206) concludes that ‘we have no concrete idea what it means to claim that these theories are approximately true’. Indeed, for him, approximate truth is ‘hopelessly vague’ (Barrett 2003, 1216).

Attempts to develop a formalized, quantitative account of approximate truth have been unsuccessful. The most widely discussed failure has been that of Popper’s verisimilitude project. Popper (1963) linked the ‘truth-content’ (the class of all true propositions that may be derived from a theory) and ‘falsity-content’ (the class of all false propositions that may be derived from a theory) with a theory’s ‘truthlikeness’ or ‘verisimilitude’. For Popper,

Assuming that the truth-content and the falsity-content of the two theories \( t_1 \) and \( t_2 \) are comparable, we can say that \( t_2 \) is more closely similar to the truth, or corresponds better to the facts, than \( t_1 \), if and only if either: (a) the truth-content but not the falsity-content of \( t_2 \) exceeds that of \( t_1 \), or (b) the falsity-content of \( t_1 \), but not its truth-content, exceeds that of \( t_2 \). (Popper 1963, 232)

Therefore, if the truth-content of \( t_2 \) exceeds that of \( t_1 \), science progresses toward the truth even when \( t_2 \) is subsequently falsified because \( t_2 \) has more verisimilitude than \( t_1 \). That is, science progresses by means of abandoning partially true, but falsified, theories in favour of theories with more verisimilitude.

The verisimilitude approach encountered significant problems as a result of articles by Miller (1974), Tichý (1974, 1978), and Grünbaum (1976), among others. These works showed that the conditions for determining the verisimilitude of theories only work when the theories are true. Therefore, because Popper’s approach was meant to apply to theories that were false, his version of verisimilitude was defective.

After Popper, other realists have developed verisimilitude approaches to approximate truth. These include Niiniluoto’s (1987a) similarity approach, which is premised on ordering the rival answers to a cognitive problem, Oddie’s (1987) likeness position, which invokes a picture theory of statements, Schurz and Weingartner’s (1987) focus on ‘relevant consequences’, and Kuipers’s (1987a) ‘theoretical truthlikeness’, which focuses on structures and sets of structures. Kuipers (1987b) classifies the first three of the preceding as syntactic approaches and the fourth as semantic. In his formal, qualitative, ‘comparative realism’ approach, Kuipers (2000, 258) argues against a
quantitative approach to truthlikeness because 'there is nothing like a natural real-valued distance function between the structures of scientific theories, let alone something like a quantitative comparison of theories based on such a distance function'. Indeed, 'quantitative intuitions concerning refined truth approximation do not seem to belong to scientific common sense' (Kuipers 2000, 316).

Despite numerous works, it is fair to say that all approaches to approximate truth have problems. Consider two examples. First, the works of Oddie (1986) and Nimiuruoto (1987b) equate truthlikeness with the distance between a possible world and the actual world. Second, Aronson, Harré, and Way (1994) develop a type-hierarchy approach that views truth as a limiting case of verisimilitude, in which truth-likeness refers to the similarity between a 'type' picked out in a hierarchy to that of the actual type. Psillos (1999) scrutinizes both the 'possible-worlds' and 'type-hierarchy' approaches and finds that, though both have merit, both are significantly flawed. As to the first, Psillos notes that 'truth-likeness turns out to possess odd features such as (a non-uniform) dependence on the number of states of the world. True propositions end up having the same verisimilitude as false ones' (Psillos 1999, 268). As to the second, he notes that its 'contextualism' creates two important philosophical problems:

(1) What—or who—is going to determine the relevant context in which the truthlikeness of a certain truth-claim will be judged? … If no objective criteria are offered, then, to say the least, the degree of verisimilitude of a truth-claim becomes conventional, and even ambiguous. (2) Suppose that one replies that we should appeal to pragmatic considerations … [H]owever … [a]n appeal to pragmatic factors, or to interests, will not disperse the charge that the claim of truth-likeness may well end up ambiguous … The result will obviously be that, even relative to a specific set of interests, a particular truth-claim could receive very different degrees of verisimilitude. (Psillos 1999, 272)

Psillos argues that a major problem that has plagued previous attempts to explicate approximate truth has been the desire to develop a formal, quantitative approach to approximate truth. Because he is 'personally sceptical about the prospects of formalising the notion of truth-likeness', he argues that the best approach might be 'a more definite qualitative explication of the notion of truth-likeness' (Psillos 1999, 278). Adopting the view of Weston (1992, 54), who argues that a 'statement will count as approximately true to the degree it is accurate in whatever it asserts', Psillos develops an 'intuitive' approach.

For his intuitive approach, 'a theory is approximately true if the entities of the general kind postulated to play a central causal role in the theory exist, and if the basic mechanisms and laws postulated by the theory approximate those holding in the world, under specific conditions of approximations'. More specifically, 'a description D approximately fits a state S (i.e. D is approximately true of S) if there is another state S' such that S and S' are linked by specific conditions of approximation, and D fits S' (D is true of S'). For him, 'a theoretical law is approximately true of the world, if it is strictly true in a world which approximates ours under certain conditions'. For example, 'the law of gases, PV = RT … is approximately true of real gases, since it
is true of ideal gases and the behaviour of real gases approximates that of ideal gases under certain conditions' (Psillos 1999, 277).

3. A Procedure for Articulating 'Approximate Truth'

I agree with Psillos (1999) that a qualitative approach, rather than a formal quantititative approach, to defining approximate truth has a greater likelihood of success. However, note that his intuitive approach is limited to those situations in which science has access to laws that are 'strictly true' in a 'world that approximates ours'. Also note that Weston (1992, 59), on whose work Psillos draws, specifically points out that the 'semantics of approximate truth sketched here allows approximation to occur only in the relations between quantity terms and the quantities they denote'. Even if we set aside these concerns, science is capable of producing laws that are 'strictly true' in any world, it is unclear that science produces theories, construed as collections of interrelated laws (among other things), that are strictly true in any world and can be reduced to Weston's (1992) 'quantity terms'. Therefore, though the intuitive approach, I argue, has merit, the specific intuitive approach of Psillos (1999) is, at least in many contexts, problematic.

I argue that the goal of articulating the concept of approximate truth in a qualitative manner can be advanced by first investigating the processes by which science accords theories the status of accepted or rejected. Understanding approximate truth by first examining theory acceptance has prima facie merit, for theory acceptance has long been associated with realists' views of truth: 'To rationally accept a theory as a basis for action is to accept it as telling us something or other about the world, and that is to accept the theory as being more or less true' (Newton-Smith 1981, 287).

My procedure for investigating the processes by which science accords theories the status of accepted or rejected will be to construct a model of such processes. Again, starting with a model of theory status has prima facie merit because, for realists, models of all kinds play a prominent, perhaps essential, role in science. Realists maintain that models often contribute to scientific understanding because, as Cushing (1991, 341) puts it, the 'understanding of physical processes ... involves picturable physical mechanisms and processes that can be pictured'. By providing a visual heuristic, Hunt (1994) shows how simple, box and arrow, path diagram models can contribute significantly to understanding complex processes. In such models or depictions, key constructs in boxes are joined by arrows representing the directions of influence produced by physical or cognitive processes. As to models in general, Morrison (2007, 210) points out that even though we can think of a model as embodying some type of representation of the phenomena under investigation, ... it contains a certain degree of representational inaccuracy'. Likewise, because in path diagram models key constructs are the only ones represented, they are partial representations.

This article uses a path diagram model as a visual heuristic for the purpose of showing the processes in science that are involved in determining a theory's status of acceptance or rejection. This 'inductive realist' model of theory status then serves as a starting point for explicating an inductive realist view of approximate truth.
(The rationale for the label 'inductive realist' will be provided in the next section.) I then argue that the inductive realist approach to articulating approximate truth developed here can explain instances of the success of science. Following the suggestion of Magnus and Callender (2004) that realist arguments should focus on 'retail' success stories, I show the advantages of the inductive realist approach through the use of a specific success of science: the successful eradication of the disease labelled 'smallpox'. I begin by giving an overview of the model.

4. Model Overview

Figure 1—which, I stress, contains only key concepts—shows my inductive realist model of theory status. The best place to 'enter' the model is at Box 1, which shows that science (interpreted here to include both individual scientists and scientific communities) proposes theories. These theories are viewed to be linguistic expressions that typically contain entities, which are proposed to have attributes, that is, properties, characteristics, and causal powers (e.g., Harré and Madden 1975). The entities are also proposed to form relationships, for example, laws, propositions, and hypotheses that constitute structures and mechanisms, which may be causal or noncausal.

The model is explicitly realist in two ways. First, the entities represented in Box 1 may be observable or unobservable, for 'a realist holds that a valid scientific explanation can appeal to the in principle non-observable' (Manicas 1987, 10). Second, consistent with scientific realism's 'metaphysical thesis' (Psillos 2000b), the theories (entities, attributes, and relationships) identified in the linguistic expressions in Box 1 are understood to be about the external-to-the-linguistic-expressions world of entities, attributes, and relationships in Box 4. It is the sharp distinction between the linguistic expressions in Box 1 and the world of Box 4 that distinguishes realism from idealism, the view that 'all reality is mental (spiritual, psychical)' (Angelas 1981, 120). Consistent with the realism of Searle (1995, 150), '[t]he world (or alternatively,
reality or the universe) exists independently of our representations of it.’ As Thagard (2007, 29–30) argues, because the best ‘scientific evidence strongly suggests that the universe is over 10 billion years old, but that representations constructed by humans have existed for less than a million, … we can infer that that there was a world existing independent of human representation for billions of years…[and] truth is not a purely mental matter.’

Path A shows that, through time, the theories proposed in Box 1 are evaluated by scientists and their communities. Any particular theory is accorded the status of acceptance just in case it is considered to be the best theory available to ‘account for’ its domain (Shapere 1985, 642). That is, a theory is accepted if it is the best theory available to explain and predict the phenomena in the theory’s domain. Therefore, an accepted theory will be recommended as the one most appropriate for guiding interventions (actions) in the specific domain of the world in Box 4 that is associated with the theory. Evaluative criteria indicated by Path A prominently include the theoretical evidence for the theory. The theoretical evidence includes the theory’s epistemic virtues, for example, its internal consistency and coherence with other accepted theories (as stressed by Thagard 2007). (The model highlights evaluative criteria associated with empirical evidence in the context of Paths G and H, which are discussed below.)

A second major status in Box 2 is that of working acceptance, in which a theory, though acknowledged by most scientists as not the best theory for a domain, is considered worthy of further pursuit by particular scientists or sub-communities of scientists. When a theory has working acceptance for particular scientists, it may or may not be recommended by them as suitable for guiding interventions in the world of Box 4, even though they view it as suitable for working on. That is, the model distinguishes the context of ‘acceptance’ from that of ‘pursuit’ (Laudan 1977, 108). As noted by Watkins (1984, 156), the failure to distinguish between a theory being worthy of acceptance and worthy of pursuit, or working on, has been a common problem in many philosophy of science works, including those of Lakatos.

The third major category is rejection, in which a theory is judged to account for a particular domain so poorly that most members of a scientific community view further pursuit on it as unwarranted. Theories with a status of rejection are also viewed as being inappropriate or unreliable for guiding interventions in the world of Box 4.

Path B shows that theories with different status in Box 2 are used differently. First, accepted theories are used to explain past and present phenomena in the theories’ domains, to predict future phenomena in tests of the theories (to further explore, to ‘flesh out’, their boundaries and characteristics), and to guide practical interventions in the world of Box 4. Second, theories with the status of working acceptance are used by their advocates, detractors, and theory-neutral investigators ‘as a good basis for further research’ (McMullin 1984, 35). Such research may consist of theoretical or empirical explorations to determine whether and under which circumstances such theories might be accepted. Third, rejected theories are not used by most scientists working in a theory’s domain, except when additional evidence surfaces. The
additional evidence that prompts re-evaluations of rejected theories often involves anomalies with respect to accepted theories, as famously argued by Kuhn (1962).

Path C shows that the entities, the entities' attributes, and the relationships (structures/mechanisms) among the entities that exist in the world of Box 4 influence the outcomes of the use of theories in Box 3. Specifically, they influence whether the explanations, predictions, and interventions will be successful or unsuccessful.

Path D shows that the use of theories in Box 3 can sometimes influence the existence and nature of the entities in Box 4. That is, even though the theories in Boxes 1 and 2 are linguistic expressions and are independent of the world in Box 4, the use of theories to explain and predict phenomena and guide interventions can change certain characteristics of the world being explained, predicted, and intervened in. For example, theories that posit correctly that specific antibiotics will be effective against bacteria may prompt the overuse of antibiotics, which can then lead to the survival of bacteria that can resist the antibiotics.

Paths E and F and Boxes 5 and 6 show that scientists and their communities evaluate or judge the outcomes of using theories to explain, predict, and intervene in the world of Box 4. Specifically, Path E and Box 5 indicate the instances of a theory that are judged to be successes. Path F and Box 6 show instances of a theory that are judged to be failures.

Paths G and H show that the successes and failures of a theory at explaining phenomena, predicting phenomena, and intervening in the world of Box 4 influence the theory's acceptance/rejection. That is, the successes and failures of a theory constitute the empirical portion of the evidence for/against it. The total evidence for/against the theory includes the theoretical evidence (represented by Path A) and the empirical evidence (Paths G and H).

I now defend the use of 'inductive realism' to describe my approach. As to successes (Box 5) and failures (Box 6), the label of 'inductive realism' is adopted because the model accepts the view that 'the long-term success of a scientific theory gives reason to believe that something like the entities and structure postulated by the theory actually exists' (McMullin 1984, 26). Note the important qualifications that McMullin (1984) places on the realist claim about the relationship between empirical evidence and belief in, or in the model's terms, acceptance of, a theory. First, the successes (Box 5) must occur over a significant period of time. That is, it is the cumulative record of successes, not some unique empirical test. Second, the successes give reason to accept a theory, but not conclusive warrant for the acceptance of a theory. That is, even with many successes, the entities and structures posited in the theory in Box 1 may not exist in Box 4. Third, the successes give reason to believe (accept) that the theoretical structures in Box 1 are something like the structures in Box 4, not that they are exactly like the structures.

Paths I and J indicate that the successes in Box 5 and failures in Box 6 influence the scientific understanding of the theories in Box 1. That is, the successes and failures contribute to providing a deeper, more detailed, more complete understanding of the entities, attributes, and relationships posited by the theories related to the empirical successes and failures. This understanding often results in significant revisions in
what are posited to exist in Box 4. That is, consistent with the realism of Stove (1982),
as a result of the processes depicted in Figure 1 over the last several centuries, science
has come to know more about the world in Box 4: 'Much more is known now than was
known fifty years ago, and much more was known then than in 1580. So there has been
a great accumulation or growth of knowledge in the last four hundred years. . . . If a
philosopher of science . . . [is] reluctant to admit this, then his position can be
rightly described as irrationalism' (Stove 1982, 3–4).

5. Truth and Approximate Truth

The inductive realist model sketched in Figure 1 has implications for truth and
approximate truth. Before articulating a proposal for approximate truth, I first
discuss what the inductive realist view maintains that truth and approximate truth
are not. First, truth is not an entity in Box 4. Truth is not 'out there' for scientists
to study. Therefore, the model denies the view of some critics of realism who maintain
that realists must assume that 'there is an immutable truth out there which scientists
can study' (Zinkhan and Hirschheim 1992, 83). Rather than being 'out there' in Box 4,
truth is an attribute of beliefs and linguistic expressions. Specifically, it is an attribute
of the kinds of linguistic expressions as those proposed by science in Box 1, including
those expressions denoted by the labels 'theories', 'laws', 'propositions', and
'hypotheses'.

Second, truth is not an attribute of linguistic expressions that can be known with
certainty. That is, inductive realism does not equate 'truth' with 'truth with certainty'.
Accordingly, the view represented by the model rejects direct realism, which is
described by Hooker (1985) as holding that human perceptual processes always
result in a veridical representation of external objects, which implies that knowledge
about external objects can be known with certainty. In contrast, the inductive realist
view argued for here is a fallibilistic realism, which maintains that, though the job
of science is, indeed, to develop genuine knowledge about the world, such knowledge
will never be known with certainty: there is no 'God's eye' view. As Siegel (1983, 82)
puts it, 'To claim that a scientific proposition is true is not to claim that it is certain;
rather, it is to claim that the world is as the proposition says it is.'

The approach to the concept truth used in the model depicted in Figure 1 is consistent
with the 'descriptive-success' version of the correspondence theory of truth developed
in Goldman (1999, 59): 'An item X (a proposition, a sentence, a belief, etc.) is
true if and only if X is descriptively successful, that is, X purports to describe reality
and its content fits reality.' For Goldman, therefore, like our inductive realist model,
truth is an attribute of the linguistic expressions identified by science as theories in
Box 1 only if (1) such expressions and beliefs purport to describe, to be about, the
reality in Box 4, and (2) the content of the expressions successfully (Box 5) fits reality.

What, then, is approximate truth? Recall that the inductive realist model of theory
acceptance adopts the realist view that 'the long-term success of a scientific theory
gives reason to believe that something like the entities and structure postulated by
the theory actually exists' (McMullin 1984, 26). My approach to defining the
meaning of 'approximately true' draws on his long-term success position even though McMullin, himself, maintains that relating success to truth and approximate truth is 'inappropriate'. Indeed,

I do not think the acceptance of a scientific theory involves the belief that it is true. Science aims at fruitful metaphor and at ever more detailed structure. ... To imply that a theory is literally true would imply, among other things, that no further anomaly could; in principle, arise from any quarter in regard to it. ... As has often been pointed out, the notion of acceptance is very complex, indeed ambiguous. ... In no case would it be correct to say that acceptance of a theory entails belief in its truth. ... The realist would not use the term 'true' to describe a good theory. ... He has no independent access to the world, as the antirealist constantly reminds him. ... The term 'approximate truth', which has sometimes been used in this debate is risky, because it immediately invites questions such as how approximate?, and how is the degree of approximation to be measured? If I am right in my presentation of realism, these questions are unanswerable because they are inappropriate. (McMullin 1984, 37)

The inductive realist approach adumbrated here disagrees with McMullin’s arguments against relating success and truth. First, contra McMullin, to accept a theory as true does not imply that one believes that 'no further anomaly could, in principle, arise'. This confounds truth with truth with certainty. Again, to claim that a scientific proposition is true is not to claim that it is certain; rather, it is to claim that the world is as the proposition says it is. One can accept a theory as true and still acknowledge that many anomalies can arise.

Second, to accept a theory as true does not imply that one has (or must have) 'independent access to the world'. The inductive realist approach fully accepts the lack of a God's-eye view. But the approach also maintains that a God's-eye view is not required to accept a theory as true. Science is fallible; inductive realism is, likewise, fallibilistic. But to accept the view that all scientific theories are fallible is not to say that all scientific theories are false. Some, perhaps many or most, may be true or, as I argue, approximately true. Inductive realism accepts 'the doctrine of fallibilism: while there is truth, there is no certainty; we get at truth by way of warrant and justification, and these are always open for further consideration' (Siegel 1997, 23).

Third, the concept of approximate truth is not doomed because of the alleged 'how approximate' question. The 'how approximate' question, I argue, stems from viewing approximate truth as being equated with a distance-function interpretation of closer to the truth. Equating approximate truth with the distance from the truth implies the necessity of both (1) knowing absolute truth (or, in McMullin's terms, knowing what is 'literally true') and (2) having a metric to measure the distance between a theory that is claimed to be approximately true and the absolute truth. Therefore, consistent with Kuipers's (2000, 258) conclusion that 'there is nothing like a natural real-valued distance function between the structures of scientific theories', I argue that equating approximate truth with a distance-function interpretation of closer to the truth is a non-starter. If approximate truth is a valuable concept, and I argue that it is, it must not be defined in such a way that it implies that one has independent
access to the world, or a God's-eye view, or a metric to measure the distance between absolute truth and approximate truth.

What, then, is the inductive realist approach to approximate truth? For the approach, three assumptions are paramount. First, consistent with Box 4 in Figure 1, the inductive realist approach assumes that entities, attributes, and relationships in the external world exist. This is what Kuipers (2007, 28) refers to as the 'preliminary ontological' position of realism. Second, the approach assumes that it is possible for Box 1 to contain true linguistic expressions related to particular sets of entities, attributes, and relationships (i.e., it is possible for theories $X^*, X^{**}, X^{***}$, etc., to be true). Third, it distinguishes the meaning of linguistic expressions from the warrant for believing them.

With the preceding three assumptions in mind, the inductive realist approach equates the meaning of (1) 'the linguistic expression identified as theory $X$ in Box 1 is approximately true' with (2) 'it is likely that the specific entities, attributes, and relationships posited by theory $X$ are something like the entities, attributes, and relationships of some true theory $X^*$. Therefore, accepting a theory (in Box 1) as approximately true is warranted when the evidence related to the theory is sufficient to give reason to believe that something like the specific entities, the attributes of the entities, and the relationships, structures, and mechanisms posited by the theory is likely to exist in the world external to the theory (Box 4).

6. Explicating Approximate Truth

The preceding section provides the inductive realist approach to defining approximate truth. This section further explicates the approach. I note five key qualifications.

First, by evidence, I mean the total evidence, including both what I label 'theoretical' evidence (Path A) and empirical evidence (Boxes 5 and 6 and Paths G and H). As to empirical evidence, as one reviewer correctly noted, the inductive realist approach developed here may be viewed as a generalization of Popper's intuitive idea of approximate truth. Specifically, Popper's true consequences and false consequences are incorporated in the more general concepts of a theory's successes and failures.

Second, as to theoretical evidence, this concept is meant to include all non-empirical epistemic virtues (e.g., logical consistency, fertility, and consistency with other accepted theories). Theoretical evidence would also include the absence/presence of important lacunae.

A theory's lacunae result from situations in which the theory gives no account, but that are not in contradiction with it. Laudan (1977, 17) calls lacunae 'anomalous problems', which are described as 'those empirical problems which a particular theory has not solved, but which one or more of its competitors have'. For Aliseda (2005, 170), lacunae are 'those phenomena which a scientific theory cannot explain, but that are consistent with it ... a(n) (individual) fact is compatible with the theory, but not derivable from it.' For Kuipers, lacunae constitute cases of 'neutral evidence'. As he formally states it, $p(E) = p(E/H)$ (Kuipers 2000, 46).
As a reviewer points out, because the inductive realist approach modelled in Figure 1 is meant to be a general model, it should account for lacunae. Indeed it should. I begin by noting that Aliseda (2005, 171) argues that the "presence of lacunae marks a condition in the direction of progress of a theory, suggesting an extension (or even a revision) of the theory." For her, therefore, "lacunae not only play a role in the evaluation of a theory, but also in its design and generation." Now, I note that Figure 1 is a dynamic, process approach to theory acceptance and approximate truth. Therefore, consistent with Aliseda (2005), for both accepted theories and those with 'working acceptance', the presence of important lacunae provides theoretical evidence that the theory is incomplete, which suggests directions that more theoretical work should be done.

Also, note that it is the presence of important lacunae that can play an important role in directing the process of theory modification. Just as Kuipers (2000, 227; emphasis added) points out that "it will always be possible to invent "empirically equivalent theories" . . . which . . . can explain the same variety of successes" as a theory under consideration, it will always be possible to invent trivial lacunae. That is, all theories are necessarily incomplete; no theory explains everything. The inductive realist approach, drawing on Shapere (1985), focuses attention on the specific domain in which a theory is supposed to be able to explain phenomena, predict phenomena, and guide interventions. For inductive realism and Figure 1, the importance of a particular lacuna is determined by scientists' expectations as to precisely what a theory is expected to explain and predict in its specific domain.

Finally, with respect to lacunae and approximate truth, important lacunae associated with a theory constitute a part of the theoretical evidence used to evaluate the theory. That is, lacunae count against the approximate truth of a theory. In comparing the approximate truth of rival theories, I agree with Douven (2005, 284) that empirically equivalent theories are rare, for indeed, "it is typically quite hard to come up with even one theory that fits the data, let alone a number of such theories." Nonetheless, in the case of two empirically equivalent theories where one rival has a lacuna, but the other does not, we may say, somewhat clumsily, that one theory is more approximately true than the other.

Returning to the five qualifications of the inductive realist definition of approximate truth, the third qualification is that the 'something like' in the definition of approximate truth does not imply exactly like. Rather, 'something like' implies that there exist entities, attributes, and structures in Box 4 that are similar to, in important ways, the entities, attributes, and structures posited in Box 1.

Fourth, the 'likely to exist' in the definition of approximate truth does not equate with 'true with probability p', in which p is considered to be a calculable number. Instead, the inductive realist approach maintains that, as Bunge (1967, 319) so aptly puts it, there is a 'weighing' of the theoretical and empirical evidence. With regard to the empirical evidence, a key consideration in the 'weighing' is the proportion of empirical successes (Box 5) relative to empirical failures (Box 6). A theory's high proportion of successes, relative to failures, gives reason to believe that the theory is approximately true. A theory's high proportion of failures, relative to successes,
gives reason to believe that the theory is likely false. Although the weighing of evidence occurs in all sciences, procedures and standards as to what counts as a sufficiently high proportion of successes for the ascription of 'approximately true' to a theory is discipline and context specific.\(^3\)

Fifth, and finally, I note that some theories may not posit entities, attributes, or relationships among entities. For example, some interpretations of quantum mechanics do not posit entities, etc. Indeed, realism is often attacked (e.g., van Fraassen 1980) for ostensibly being committed to finding entities or 'hidden variables' that will turn quantum mechanics from an indeterministic set of equations to a deterministic process (McMullin 1984). In contrast, the inductive realism proposed here argues that the success of those theories that are posited to contain entities gives us reason to believe that something like the entities so posited by the theories likely exists. Therefore, with respect to quantum mechanics, if the best interpretation of quantum mechanics (or any other theory) is one that does not posit the existence of entities, so be it; no damage occurs to inductive realism and its explication of approximate truth.

However, the fifth qualification notwithstanding, most scientific theories are linguistic expressions that do, indeed, posit entities, attributes, and relationships, as shown in Box 1. Furthermore, most scientific theories do purport to describe the world in Box 4. Therefore, for these theories—which constitute most theories in science—inductive realism equates (1) 'the linguistic expression identified as theory \(X\) in Box 1 is approximately true' with (2) 'it is likely that the specific entities, attributes, and relationships posited by theory \(X\) are something like the entities, attributes, and relationships of some true theory \(X^\ast\)'.

7. A Macro Success of Science: Smallpox Eradication

I now use the model in Figure 1 and our concept of approximate truth to explain an example of success in science. Magnus and Callender (2004, 321) urge writers to distinguish 'retail arguments' for realism from 'wholesale arguments'. The former refer to arguments 'about specific kinds of things such as neutrinos', and the latter refer to 'arguments about all or most of the entities posited in our best scientific theories'. Therefore, I focus on one 'retail' success story and further distinguish between the story's 'micro' successes (e.g., specific instances of the successful application of a theory to explain or predict a phenomenon) and 'macro' successes (e.g., the successful application of a theory to a group of phenomena).

I use as a macro success an example from medical science, the eradication of the disease labelled 'smallpox'. This macro success is shown to be the conjunction of a host of micro successes (e.g., specific, theory-guided interventions that saved individuals from the scourge of smallpox). First, I review briefly the smallpox success story.

The disease called smallpox plagued the human community for thousands of years. Numerous references to a disease with symptoms like smallpox have been found in the records of ancient India and Africa. For example, an analysis of the remains of several Egyptian mummies shows evidence of smallpox. In any respect, by the Middle Ages
smallpox was a scourge in most of Asia, Africa, and Europe; three million people died of smallpox in India’s 1769 epidemic; by the end of the eighteenth century, Europe was losing over 400,000 people each year to smallpox; and it was responsible for over one-third of all the blindness in eighteenth-century Europe.

By the early part of the eighteenth century, it was widely recognized that people who once had smallpox seemed never to get the disease again. Furthermore, several European countries began adopting inoculation (as distinguished from ‘vaccination’) procedures to prevent people from acquiring the disease during an epidemic. With the inoculation procedure, which had been used in Asia for several hundred years, a subject was injected with material from a smallpox lesion obtained from an infected person. Inoculation became commonplace in England after a publication of the Royal Society, authored by James Jurian, showed that, whereas the risk of dying from smallpox from the inoculation was about 1%, the overall risk of dying from smallpox was about 12%, and in times of epidemics the risk rose to about 20%. However, in addition to the risk of death, the inoculation procedure also had the disadvantage that the inoculated person could spread the disease to others.

Edward Jenner (1749–1823) was a physician who lived in Berkeley, England. He, for years, had heard rumours to the effect that women in rural areas who had been infected by the mild disease called ‘cowpox’ never contracted smallpox. Intrigued, Jenner began gathering data on those who claimed to be immune from smallpox because they had already had cowpox. The data seemed to confirm the claims of the rural women. However, Jenner wondered, would someone inoculated with cowpox be immune from smallpox? On 14 May 1796, Jenner inoculated one James Phipps with cowpox material taken from a sore on the hand of an infected milkmaid. He called the inoculation ‘vaccine’, from the root word vacca, which is Latin for ‘cow’. The child developed a mild reaction similar to that of a favourable smallpox inoculation. On 1 July, Jenner inoculated the boy with smallpox material taken from an infected patient, and the inoculation produced no significant reaction (because, we now know, the vaccination caused the boy’s immune system to produce smallpox-protecting antibodies). Elated with the results, Jenner repeated his experiment on five more children in 1798, when a fresh outbreak of cowpox next made the virus available to him. After the experiments yielded the same positive results, Jenner triumphantly announced his findings in a small pamphlet.

Within a few years, Jenner’s experiments were repeated on much larger samples, and ‘vaccination’ procedures with cowpox virus became commonplace. Eventually, the cowpox virus used for smallpox vaccination was replaced with the vaccinia virus. By 1900, vaccinations for smallpox had largely eliminated the disease in the United States and Europe. Nonetheless, smallpox continued to kill hundreds of thousands of people each year well into the twentieth century.

It should be pointed out that Jenner never observed what is now labelled a ‘virus’ in his entire life. Although the ‘germ theory’ of contagious diseases was actively being promulgated during his time, it was not widely accepted. (For some medical scientists, the germ theory had the status of ‘working acceptance’ in Box 2 of Figure 1.) In 1836, using the recently invented achromatic microscope, Agostino Bassi (1773–1856) was
the first person to isolate a specific microscopic organism that causes a disease. In this case, he isolated a parasitic fungus that causes a disease common in silkworms. In 1898 Loeffler and Frosch demonstrated that some diseases were caused by micro-organisms so small that they would pass through a very fine filter. Such micro-organisms came to be known as 'filterable viruses', and the organism causing smallpox came to be known as one of these, which was labelled the 'variola' virus, from the Latin varius, meaning spotted. It was only in 1947, with the invention of the electron microscope, that anyone saw a virus. The advent of the electron microscope brought about rapid advances in our knowledge of the characteristics and properties of the smallpox virus, including its internal chemistry and how it is able to attack human cells and force them to reproduce the virus.

It was well known by the time of the electron microscope that the smallpox virus could not reproduce itself outside a human host. Therefore, if there ever came a time when no one in the world had smallpox, the disease—according to theory—should be completely eradicated. This was the programme adopted by the World Health Organization (WHO) at its 1966 meeting in Geneva. At that time, 44 countries were still reporting smallpox and the disease was endemic in 33 of them. The WHO set a deadline of 10 years for the eradication of the disease through massive vaccination programmes. The last known case of smallpox—as of this writing—was in 1978, when the virus escaped from a laboratory in Birmingham, England. In 1980, the thirty-third World Health Assembly accepted the final report of the Global Commission for the Certification of Smallpox Eradication.

8. Explaining the Success of Smallpox Eradication

The eradication of smallpox is a significant, macro-success story of medical science. How can this success be explained? For simplicity, as to Box 1 in the inductive realist model, let us refer to the overall theory proposed as ‘smallpox theory’. Note that the theory posits numerous entities (E), which are characterized as having attributes (A), and are theorized to causally relate (CR) to other entities. As examples of entities, we have: \( E_1 = \text{smallpox disease} \); \( E_2 = \text{cowpox disease} \); \( E_3 = \text{‘virus’} \); \( E_4 = \text{‘variola virus’} \); \( E_5 = \text{‘vaccinia virus’} \); and \( E_6 = \text{‘antibodies’} \). As examples of the attributes of entities, we have: \( A_1 = \text{smallpox is characterized by a rash and high fever} \); \( A_2 = \text{viruses are smaller than bacteria} \); and \( A_3 = \text{the variola virus cannot exist outside a human host} \). As examples of entities theorized to causally relate to other entities, we have: \( CR_1 = \text{vaccinating people with material from cowpox lesions will prevent the occurrence of the smallpox disease} \); \( CR_2 = \text{the vaccinia virus will cause the body to produce antibodies} \); \( CR_3 = \text{the antibodies produced as a result of vaccinating people with vaccinia virus can successfully attack the smallpox virus} \); and \( CR_4 = \text{antibodies successfully attacking the smallpox virus will prevent smallpox disease from occurring} \).

As to Box 3, note that predictions (P) also played a key role in the success story. For example, \( P_1 = \text{if a person is vaccinated with material from a cowpox lesion, then a subsequent inoculation with material from a smallpox lesion will produce no reaction} \);
If there should ever come a time when no one in the world has smallpox, then the smallpox disease will be completely eradicated. Also, as to Box 3, recommended (and subsequently implemented) interventions (I) occurred. For example, \( I_1 = \text{people should be vaccinated to prevent smallpox}; I_2 = \text{a worldwide vaccination programme should be implemented.} \) As to Box 5, there were millions of micro successes, as the vaccinations proved to be extraordinarily successful in preventing smallpox. As to Box 6, there unfortunately were some failures, because there were some people for whom the vaccination did not prove effective. But the ratio of the total of micro successes to total micro failures was very high. Finally, as to Box 1, the many medical investigations prompted by the study of smallpox provided a powerful spur to developing medical science’s understanding of immunology.

The inductive realist explanation of the successful eradication of smallpox is that ‘smallpox theory’ is approximately true. That is, it is likely that something like the entities (e.g., \( E_1 \), etc.), attributes of the entities (e.g., \( A_1 \), etc.), and causal relationships among the entities (e.g., \( CR_1 \), etc.) posited by ‘smallpox theory’ exist. The following is a highly summarized form of the explanation, in which statements 1 through 7 constitute the explanans, and statement 8 is the explanandum:

1. Something like the entity denoted by ‘smallpox disease’ likely exists.
2. Something like the entity denoted by ‘smallpox virus’ likely exists.
3. Something like the entity denoted by ‘antibodies’ likely exists.
4. Something like the entity denoted by ‘vaccinia virus’ likely exists.
5. Vaccinating people with vaccinia virus will likely cause the body to produce antibodies that can successfully attack the smallpox virus.
6. The antibodies that are produced as a result of vaccinating people with vaccinia virus will likely prevent them from contracting smallpox.
7. The smallpox virus likely has the attribute that it cannot exist outside human subjects.
8. Therefore, statements one through seven explain why instituting a massive vaccination programme throughout all parts of the world where smallpox existed was successful in eradicating smallpox.

The preceding argument shows how inductive realism’s concept of approximate truth can contribute to explaining the millions of micro successes that constitute the macro success of smallpox eradication. Note that the explanation employs approximate truth, but does not rely on ‘smallpox theory’ being ‘strictly true’ in any world, as would the intuitive approach of Psillos (1999). Likewise, the explanation does not require a metric for measuring how close ‘smallpox theory’ is to any ‘strictly true’ or ‘literally true’ theory.

Recall Putnam’s (1975) wording in his original ‘no miracles’ claim: a version of realism is the only—not the best, but the only—philosophy that does not make the extraordinary success of science a cosmic coincidence or miracle. As previously discussed, in the decades since the origin of the ‘no miracles’ claim, efforts to find a non-coincidental, non-miraculous alternative to scientific realism’s approximate
truth explanation have foundered. But coincidences, of course, do indeed happen. Therefore, consistent with inductive realism’s commitment to fallibilism, it must be acknowledged that it is possible that each of the micro successes in the eradication of smallpox was a coincidence. If so, then the macro success of the eradication of smallpox would justify Smart’s (1963) appellation of ‘cosmic coincidence’.

Sometimes, studying failures (Box 6) helps us understand successes (Box 5). Note that explaining the failure of a programme like the smallpox eradication programme—if it had, indeed, failed—would be easy. For example, if the injections of vaccinia virus do not cause the body to produce antibodies, then the eradication programme would likely have failed. Similarly, if the smallpox virus does not have the attribute that it cannot exist outside human subjects, then the eradication programme would likely have failed. But as to the success of the smallpox eradication programme, absent some version of scientific realism, with its reliance on truth and approximate truth, one is left with the highly unsatisfactory explanation of ‘cosmic coincidence’ or ‘miracle’.

**9. Conclusion**

This article (1) develops an inductive realist, path diagram model of the processes in science that are involved in determining a theory’s status of acceptance, working acceptance, and rejection, (2) uses the model to explicate an inductive realist view of approximate truth that neither requires science’s theories to be ‘strictly’ true in any world nor requires a metric measuring ‘how close’ an approximately true theory is to some ‘strictly’ true theory, (3) uses the inductive realist approach to approximate truth to explain a ‘retail’, macro-success story, the eradication of smallpox. Although I argue that this article shows how the inductive realist approach can satisfactorily explain one important success story, and I maintain that there are numerous ‘retail’ success stories in science that the inductive realist approach can satisfactorily explain, I do not argue here that the inductive realist approach resolves the ‘wholesale’ question of the success of the entire enterprise denoted by ‘science’. Much more work needs to be done on the wholesale question. In particular, consistent with the recommendations of Magnus and Callender (2004), it would be useful to investigate other retail success stories using the inductive realist approach to approximate truth sketched here.

In closing, I point out that the inductive realism posited here contributes not only to explaining the success of science but also to understanding many of the actual practices of science. Returning to ‘smallpox theory’, note again the importance in the theory of scientists investigating the attributes of the entities. For example, note the importance of determining the size of the viral entity, its shape, its chemical composition, and its means of penetrating human cells. Only a version of realism warrants the exploration of these kinds of issues. To work toward better descriptions and better measures of the attributes of non-existing entities is irrational. Absent the belief in a version of realism, the issues could only be investigated by a researcher engaging in the following pretence: ‘Even though I do not believe that viruses exist, I shall pretend to do so to attempt to explore precisely how large these nonexisting entities are.’ Inductive
realism holds that researchers do not in fact engage in such elaborate rituals of pretending or self-deception.\footnote{5}

Likewise, note the importance in 'smallpox theory' of scientists investigating the relationships among the entities. For example, how does the vaccinia virus cause the body to produce antibodies that can successfully attack the smallpox virus? Note that to explore such a question without believing in the existence of the entities involved and their relationships with other entities would, again, involve an elaborate pretense: 'Even though I do not believe that the vaccinia virus exists, I shall pretend to do so to attempt to explore precisely how this nonexistent entity produces the antibodies that I also do not believe exist.' Again, inductive realism holds that researchers do not in fact engage in such pretences.

Return again to the original 'no miracles' argument: 'Realism is the only philosophy that does not make the success of science a miracle' (Putnam 1975, 75). This article and our discussion of pretences and self-deception rituals imply the following as an emendation of the argument: realism is the only philosophy that does not make (1) the success of science a miracle and (2) many of the actual practices of science a charade. For inductive realism, no miracles, no charades.

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Notes

[1] 'Linguistic expressions' is used here in a broad sense that includes natural languages and formal languages, such as mathematics.

[2] Although the inductive realist model incorporates structures as forms of relationships, it is not restricted to 'structural realism', as this term is used by Worrall (1989) and others.

[3] The statistical procedure known as 'meta-analysis' is used as part of the weighing process in many disciplines, including medicine, psychology, education, and sociology. For an introduction to this procedure, see Hedges and Olkin (1985).


[5] The smallpox eradication programme was also an administrative and political success story worthy of explanation. However, my focus here is on the medical science portion of the success story.

[6] Note that, for inductive realism, a smallpox researcher would say, 'Because of the long-run success of "smallpox theory", I have reason to believe that something like the entity denoted as "smallpox virus" likely exists, and I shall then explore precisely how large this entity is.'

References


