Inference to the Best Explanation and Theoretical Entities

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Scientific entity realism has been challenged on the grounds that it depends on the controversial principle of inference to the best explanation. I defend the view against this challenge, by showing that the particular inferences needed by the entity realist do not have the objectionable features antirealist's cite in questioning inference to the best explanation. Indeed, these inferences are either ones needed by empiricists in arguing for empirical adequacy, or which are no stronger than the realist needs for justifying his claims about ordinary objects.

I. Introduction. Much of the discussion about realism in the philosophy of science has stalled over the issue of explanation. Most arguments for realism rely on some form of inference to the best explanation to establish the existence of unobservable entities and the truth of theories about such entities.[1] On the other side, antirealists typically deny the legitimacy of inference to the best explanation (henceforth IBE), at least when it is used to make inferences about unobservables.[2] One intermediate position, which appears might avoid the stalemate, is the view advocated by Hacking and Cartwright, which embraces certain theoretical entities, but is antirealist with respect to theories.[3] Both Hacking and Cartwright argue that the explanatory virtues of a theory do not provide reason to maintain that the theory is true, and are accordingly adamant that the scientific entity realism they embrace does not rely on IBE.[4]

Recently, Hacking's version of scientific entity realism has been criticized for not offering a genuine alternative to general realism about theories, on the grounds that the position must invoke IBE after all (Reiner and Pierson 1995). I will argue here that they are correct in that the scientific entity realist must invoke a form of IBE. However, there are important distinctions that can be made between different forms of IBE. My aim here is to show that where entity realism

may be said to rely on IBE, it is a form of IBE that either empiricists also invoke, or that no stronger claim is made than is needed to avoid general skepticism. This stands in contrast to applications of IBE used to ground realism about scientific theories as a whole, which depend on much more dubious forms of IBE.

2. Scientific Realism and IBE. Scientific Realists have appealed to IBE to justify their belief in the truth, or approximate truth, of scientific theories in two ways. Not only is IBE used to argue for the truth of individual theories, such as the atomic hypothesis, and with it the existence of atoms, but also for the general reliability of the scientific method. Boyd, for example, has provided a general defense of scientific realism, as offering the best explanation of the reliability of the scientific method as a whole (Boyd 1991). In response, Fine argues that Boyd's use of IBE begs the question, since at least part of the dispute over scientific realism just is a dispute about the legitimacy of IBE. Boyd's reply hinges upon the fact that science does rely upon abduction, not only in drawing conclusions about unobservables, but observables as well. His chief claim here is that by eschewing IBE, antirealists will be unable to avoid the conclusion that inductive generalizations about observables are unjustified.

Whether or not it is correct that the antirealist can avoid a form of skepticism about observables only by a general acceptance of IBE, scientists do apparently use abductive methods. Certainly they use explanatory criteria to select among theories, and typically a fair degree of credence is placed in the theory so selected.[5] However, it may well be suggested that the use of

abduction has produced more failure than success. The history of science is littered with discarded theories that apparently were taken as the best explanation of some phenomena at the time. In many of these cases, it must be acknowledged from the present standpoint that not only was the preferred theory false, but that all of the considered alternatives were as well. Examples of this sort involving both general and highly specific theories can be found covering a wide variety of phenomena. The history of medicine provides many examples from the humoral theory of disease to the more recent case involving the theory that stress is a major source of peptic ulcers, which was revised in light of findings that a great many of such ulcers are caused by the heliobacter pylori bacterium. Certainly, choosing the theory that best explains will not lead us to a true theory, if no true theory is among the options considered, as in the ulcer example.[6] This is generally a problem, since we are seldom able to really consider all possible options.

IBE does not look any more promising as a reliable method of arriving at true theories when we reflect on what are generally considered explanatory virtues, as antirealists have often complained. We tend to look for explanations which are simple and which unify phenomena, but why should we expect such features to be a mark of truth? To the contrary, if indeed we live in a messy and chaotic universe, then these features may very well be a sign of falsehood. There are then good reasons to be suspicious of appeals to explanatory virtues to justify the acceptance of theories, both for low level scientific theories and grand theories concerning the success of science.[7]

This, of course, does not mean that instances of IBE are always unwarranted. For

instance, Nancy Cartwright has suggested that, while general IBE is unwarranted, scientists reasonably infer to the most probable cause. Considered simply as a form of inference, inference to the most probable cause is legitimate in a way that general IBE is not. The inference:

(1) A causes B

B

A

is valid. It follows from this that if A is the most probable cause of B, then the truth of B provides more reason to believe in A than in the other possible causes of B. However, while inferences in the form of (1) are valid, there are difficulties in determining the truth of the first premise, which need not occur in the case of the more dubious form:

(2) A best explains B

B

A

Where the quality of an explanation is gauged in terms of such features as simplicity or unification, the assumption is that we can determine which theory is best by inspection. However, almost everyone will agree that we cannot tell by inspection that A causes B or that A is the most probable cause of B. We must appeal to background conditions to ascertain the truth of such causal claims. If the background conditions justify the causal premise, then an inference to the most probable cause will be licensed, provided that what is taken as the most probable cause is indeed sufficiently probable itself. This shows that there are special cases of IBE which are legitimate.

Inference to the most probable cause and other special cases of IBE will be taken up again, after I discuss the central features of Hacking's case for entity realism and the charge that his involves a covert appeal to IBE.

3. Hacking's Case for Realism about Entities. Hacking can be read as presenting two arguments for theoretical entities in his book Representing and Intervening. The first argument is intended to show that, under certain circumstances, we have excellent reason to believe in very small objects that can be viewed only with the aid of microscopes or other instruments. A second, though related argument, addresses the reasons for believing in entities, such as electrons, which can only be detected by instruments indirectly, and which are in principle unobservable. I will consider these cases in turn.

In the first argument, which concerns cases where entities are detected with microscopes, Hacking addresses the special problem that arises in the philosophy of science of distinguishing real effects from artifacts.[8] This problem arises because when instruments are used in making observations, artifacts can be introduced by means of the viewing apparatus. In the case of microscopes, advances in technology provide the tools for distinguishing artifacts from real entities. Hacking describes how it is possible to produce microscopic grids, which can be used to identify bodies using a microscope. The grids are made by taking line drawings, photographically reducing the grid and then depositing metal on the reduced lines. When the finished grid is viewed through a microscope, we are able to see the lines of the grid clearly, regardless of the

type of microscope used. Hacking then asks

> Can we entertain the possibility that, all the same, this is some gigantic coincidence?.. .Is it a gigantic conspiracy of 13 totally unrelated physical processes that the large scale grid was shrunk into some non-grid which when viewed using 12 different kinds of microscopes still looks like a grid? To be an antirealist about that grid you would have to invoke a malign Cartesian demon of the microscope. (Hacking 1983, pg. 203)

Under these circumstances, Hacking concludes it would be astounding, if the structures observed through a microscope were unreal.

Hacking's second argument addresses entities, such as electrons, that can be detected, but not observed. Hacking argues that we have convincing evidence for such entities when we are able to manipulate them to regularly produce certain effects. Hacking's chief example here is the use of the electron gun, Peggy II, which allows physicists to isolate certain electron effects in order to investigate the properties of weak neutral currents. Of this case, Hacking writes:

> We are completely convinced of the reality of electrons when we regularly set out to build and often enough succeed in building-new kinds of device that use various well-understood causal properties of electrons to interfere in the more hypothetical parts of nature. (Hacking 1983, pg. 265)

There are some differences between the two arguments. In the first, as Hacking points out, the key problem is to distinguish real entities from artifacts of the observation process, whereas in the second the contrast is between real entities and mere tools of thought. There are important similarities, including the crucial fact that both depend on the claim that it is

manipulation which provides our grounds for belief. I will return to this point, after examining the claim that Hacking's argument depends on a contentious application of IBE.

4. Distinguishing Real Effects from Artifacts. In the first part of his book, Hacking makes it clear that he regards explanation as providing at best weak grounds for belief (Hacking 1983, pp. 52-3). Still, Reiner and Pierson charge that both of the arguments Hacking gives to establish scientific entity realism rely on IBE after all. I will consider their charge that Hacking's first argument requires IBE here and their claims against his second argument in the next section.

Hacking's first argument involves the question of how potentially observable objects can be distinguished from artifacts. His main example involves viewing so-called dense bodies through a microscope. He says of the dots observed in such circumstances that "it is no 'explanation' of this to say that some definite kind of thing (whose nature is as yet unknown) is responsible for the persistent arrangements of dots" (Hacking 1983, pg 202). Of this Reiner and Pierson say that it is nevertheless an explanation of such phenomena that they are caused by a real entity, or an artifact (Reiner and Pierson 1995, pg. 64). They conclude that Hacking's argument invokes explanatoriness as a mark of truth, and hence that it rests on no more stable ground than other arguments for scientific realism.

Reiner and Pierson appear to claim here that since the existence of a certain real entity would explain the observed phenomena, the inference to the existence of such an entity must depend on regarding explanatoriness as a mark of truth. But, this is non-sequitur. The fact that P

explains Q, and an inference is ultimately made to P, does not mean that the basis for inferring P was its explanatory power. Suppose, for simplicity, that two possibilities P and not P are under consideration, and that P would explain the known fact Q. If evidence is obtained that is incompatible with the falsity of P, we may infer that P is true. Although P explains Q, its explanatory power need not be invoked in inferring that P is true. The upshot here is that care must be taken to see that it is really explanatory power that is relied upon in distinguishing real entities from artifacts, and if so whether its use is genuinely controversial.

Consider again the viewing of dense bodies through a microscope. We rule out the possibility that they are merely an artifact of our observational procedure by varying the samples, the techniques for preparing the slides, as well as checking the microscope for defects, and perhaps using different types of microscopes. When the phenomena persist through these variations in the experimental procedure, we conclude that we are not viewing an artifact, because it would be an amazing coincidence for all of the different procedures to yield the same artifact.[9] Is this argument from coincidence just a case of IBE? Well, it may be considered a form of IBE, for the claim that the dense bodies are real and not an artifact explains why they persist through variations in the experimental procedure. However, the inference here does not rest on the simplicity or general organizing features of the explanation as indicating the truth of the hypotheses, but rather on the fact that as a matter of chance, it is highly unlikely that if an artifact were present that it would not be revealed by varying the experimental procedures. The suggestion here is that the inference is analogous to inferring that the pair of dice given to me are

fixed after I role snake eyes 1000 times in row. Here too the hypothesis that the dice are fixed explains why I keep rolling snake eyes and nothing else. But, it is not the general explanatory features that I rely upon in making the inference, but rather the extremely low probability of such of result if the dice were fair. Such arguments from coincidence, while a form of IBE, rest on background conditions which establish that a particular outcome is implausible.[10]

In any case, it is a mistake to think that Hacking's argument for the reality of objects visible only with the aid of a microscope or other device reduces to the argument from coincidence used to distinguish real effects from artifacts. The fact that we have good reason for believing that an observed phenomena is real, and not an artifact, is insufficient to provide a response to antirealist positions in the philosophy of science, such as van Fraassen's constructive empiricism. Suppose that experimental procedures sanction ruling out the presence of an artifact in favor of the claim that a new virus X has been discovered. The constructive empiricist may well say that such evidence does not discriminate between the claim that there is a virus X and that all the appearances are as if there is such a virus. Indeed, the constructive empiricist will see the argument from coincidence to distinguish 'real' entities from 'artifacts' as critical to good scientific practice, just as much as the realist does. The discovery that our observation of X is what the realist calls an artifact shows that theories entailing that there really are X's are not empirically adequate, for this means that we have not located a genuinely stable observable phenomena. If what I have said here about the constructive empiricist is correct, the inference Hacking makes in distinguishing real effects from artifacts does not involve any principle not

required by the empiricist as well. This also means that Hacking's argument for realism about certain entities which cannot be viewed unaided relies on more than what he says about how real entities are distinguished from artifacts. I shall return to this point after taking up the charge that Hacking's manipulation argument depends on IBE.

5. The Argument From Manipulation and IBE. Hacking's case for scientific entity realism hinges upon his claim that we have evidence for entities when we are able to manipulate them. This is true for both those entities that can be observed only with the aid of special instruments and those which are in principle unobservable for us. In discussing the former case, Hacking writes, "we are convinced not by a high powered deductive theory of the cell...but because of a large number of interlocking low level generalizations that enable us to control and create phenomena in the microscope" (Hacking 1983), pg. 208. Does the manipulation argument involve a covert appeal to IBE? Reiner and Pierson claim that it does. They argue that laboratory manipulations do not give us direct access to entities, such as electrons, that are in principle unobservable, but only to observable characteristics of the experimental apparatus. From this they conclude that

> Only by IBE can we come to believe that these observable signs indicate the presence of causal interactions, that these interactions are not artifacts, and that entities lie behind them.
> Moreover, only by *additional* IBE can we take the evidence as warranting belief in the existence of exactly one kind of entity, rather than two kinds or a thousand kinds. (Reiner and Pierson 1995, pg. 67)

Such remarks do little more than charge Hacking with relying on IBE, without showing why this must be so. Moreover, the claim that our laboratory manipulations do not give us access to unobservables begs the question, since Hacking's claim is precisely that when scientists "spray electrons" there is a causal relationship between the macroscopic manipulations of the scientist and electrons. The question is whether the scientific entity realist can provide an account of why we are justified in believing in electrons that does not at some point appeal to IBE in a way that the empiricist can satisfactorily avoid. It is this problem that I will focus on directly in the remainder of the paper.

As already discussed, realism about a particular type of scientific entity X requires ruling out X as an experimental artifact. I have already argued that this involves giving an argument from coincidence; but, although such arguments may be considered a form of IBE, they are not generally contested by antirealists. What the entity realist must show is that in distinguishing 'real' entities from artifacts he does not need to invoke the truth or approximate truth of a theory, where its truth in turn gets established by a controversial application of IBE. I suggest that this is exactly what Hacking tries to establish for the case of objects viewed through a microscope in his argument from the grid. His point there is that we do not need an underlying theory that organizes all of the relevant phenomena, whose truth we would establish by IBE, in order to distinguish artifacts of the experimental apparatus from real effects. No underlying theory is needed here, because indeed there is no such theory. "The argument from the grid requires a

healthy recognition of the disunity of science, at least at the phenomenological level" (Hacking 1983, pg 203).

While there may be no grand theory that is invoked here, the objection will surely be raised that some theoretical assumptions are necessary. In concluding that the dense bodies viewed through a microscope are real and not artifacts, we clearly do rely on a general understanding of how various types of microscopes work, how the slides were prepared etc., and our understanding will generally involve what may be called theoretical properties. The building and employment of Peggy II to investigate weak neutral currents reveals an even greater reliance on theoretical properties; in this case theoretical properties of electrons.[11] The question though is whether, in the first case, we rely on a general theory of light in much of its detail, including perhaps claims that light is a particle, or whether we only make use of some very basic properties of light, say, involving diffraction phenomena. In the second case, the issue is whether the truth of high level quantum mechanical theory must be assumed or whether we depend only on an understanding of some key properties of electrons, involving for example their spin. Hacking's case depends on the plausible claim that it is the latter.

What about the claim that IBE is needed to infer the presence of a causal interaction? In an interesting paper on Cartwright, Mayo argues that causal inferences can sometimes be made on the basis of experiment, which avoid appeals to IBE. She gives as a detailed example an account of Perrin's experiments on Brownian motion. These experiments were taken to show that Brownian motion is caused by random collisions of molecules, and convinced even skeptical

scientists of the reality of atoms. Demonstrating that the hypothesis H, that molecular motion, produces observed motions requires first that pr(e/H) is high. What Mayo points out is that establishing this is insufficient to avoid appeal to IBE, since there are alternative hypotheses H' for which pr(e/H') are also high. In order to avoid appealing to IBE to conclude that H is true, it must also be shown that pr(e/not H) is low. Mayo shows in some detail how Perrin was in fact able to employ statistical reasoning to satisfy both conditions, and show that Brownian motion is caused by random collisions of molecules, without appealing to IBE to rule out alternative theories.

It is critical to note, however, that in ruling out alternatives to the hypothesis that molecular collisions cause Brownian motion, Perrin showed that it is highly implausible that Brownian motion is caused by some phenomenon that is empirically distinguishable from molecular motion. Perrin did not rule out alternatives to the molecular theory that are empirically equivalent to it, nor could any experiment have done so, since what it means for two hypotheses to be empirically indistinguishable is that no empirical observations could discriminate between them. Mayo notes that there is nothing in Perrin's work that prohibits construing the causal hypothesis instrumentally. It is then at this point that IBE might seem to be required to infer that atoms exist, rather than perhaps to some other entities that are part of a theory which is empirically equivalent to the atomic hypothesis. Next, I turn to the scientific entity realist's prospects for avoiding IBE at this point.

6. Entity Realism Vs Constructive Empiricism. I have been arguing that there is a sense in which the scientific entity realist can establish that certain effects are real, rather than artifacts, and that certain causal claims are correct, without contentious applications of IBE. However, nothing in these realist arguments prevents the empiricist from withholding belief in the realist's claims about causal connections or from interpreting them instrumentally. Interestingly, I do not think that a scientific entity realist, such as Hacking, will find this fact troubling. Hacking is quite clear that he thinks that the realist can gain no ground at the level of theories (Hacking 1983, pg 55), for once we have ascended to the theoretical level, the empiricist will raise the specter of empirically equivalent theories. However, the claim that A causes B is a kind of theoretical claim, and so is subject to the empiricist's tactics.

What sort of response can the realist make? One could try the strategy Boyd suggests of trying to show that the empiricist is really committed to IBE after all, or is arbitrary in his selective application of IBE. Recall that the idea is to show that the empiricist needs IBE to justify claims about physical objects and their properties. This may involve showing that IBE is needed either to justify our basic beliefs about the existence of such objects and their properties or to justify inductive generalizations about collections of such objects. I will concentrate here on the former.

There are three general approaches that can be taken in accounting for our knowledge of physical objects. An empiricist, such as van Fraassen, who accepts that we have access to physical objects and reasonably make inductive generalizations about such objects, could take

some version of each approach. First, he could claim that we apply a restricted version of IBE, that applies to middle sized objects, but not microscopic ones, in order to infer that physical objects exist. The difficulty here is that the restriction of IBE to observables seems quite arbitrary, so that while the empiricist position remains possible, it is not compelling. The second possibility is to reject the idea that we infer the existence of physical objects at all. From this one can either simply postulate that we have access to physical objects, or one can try to give an account of our relationship with them that can account for our knowledge. Since, the former option is rather unsatisfactory, I will concentrate on the latter. The empiricist has fairly little to say about the relationship between physical objects and ourselves, to account for our knowledge of them. The realist, on the other hand, may explain how we can have knowledge of physical objects in terms of our causal interactions with the world. How do I know that there is a cup of coffee on my desk? By seeing it, picking it up, and taking a sip. How do I know that a stick in the water is straight, and not bent? By feeling it or by removing it from the water and looking at it, in other words, by interacting with it.

Now, rather than invoking IBE to justify our claims about ordinary objects, the realist may instead give a different kind of account, along the lines above, in terms of our physical connection with everyday objects. What I suggest is that this tactic is at the heart of Hacking's idea that our ability to manipulate theoretical scientific entities forms the basis for our knowledge of them. The idea here is that very small physical objects, just as much as middle sized objects, are causally related to us, and that we learn about such objects in essentially the same way as we learn about

middle sized objects, by interacting with them, not by inference.

With this picture in mind, the importance of Hacking's insistence that real entities can be distinguished from artifacts and that scientists can build devices, such as Peggy II, to manipulate unobservables without relying on high level theories becomes clear. If our ability to perform these tasks required accepting the truth of high level theory, which must be established by inference, then the scientific entity realist would apparently have to rely on IBE, in the way that the traditional scientific realist must. Additionally, we can see how the scientific entity realist will answer the objection that IBE must be used to conclude that what is manipulated is just one sort of entity, rather than two or more. This of course is determined in exactly the way that I determine that the two apples in my refrigerator are the same kind of thing, rather than two different kinds of thing. I examine them and see that they have the same basic properties.

Of course, some will object that the picture sketched here about how we have knowledge of ordinary middle sized objects also must make some appeal to IBE. Consideration of this point is well beyond the scope of the present paper. However, even if it is correct that scientific entity realism requires a controversial application of IBE for the reasons that ordinary realism does, scientific entity realism represents a middle ground between traditional realist and antirealist positions in the philosophy of science.

Endnotes

1 . See especially, (Boyd 1984).

2 . See especially (Fine 1984) and (Van Fraassen 1980).

3 . For an extended presentation of this position, see (Hacking 1983) and (Cartwright 1983).

4 . Entity Realism promises other virtues as well as avoiding appeal to IBE. Perhaps chief among these is the fact that while entity realists are not required to deny that some theories are true or approximately true, they are not committed to specifying what is to be meant in saying that our best scientific theories are approximately true. Typical realists gloss over this problem, no doubt because it is difficult, but it is a weakness that what is generally taken as the central claim of scientific realism is extremely vague.

5 . Of course, van Fraassen disputes the claim that reasons for acceptance provide compelling reasons for belief. However, the constructive empiricist does aim to accept theories which are empirically adequate. So, the question for the empiricist is whether such abductive methods tend to pick out empirically adequate theories.

6 . Nor will IBE lead to even an empirically adequate theory, if none is among the contending theories.

7 . For arguments that raise doubts about applying IBE to argue that successful scientific theories are likely to be true, see (Laudan 1981).

8 . Although this is a special problem for the philosophy of science, there are important parallel between it and the classical problem of illusion.

9 . Mayo discusses Hacking on this point in (Mayo 1996, pp. 121-2)

10 .. Day and Kincaid argue persuasively that in general it is background conditions that account for the legitimacy of IBE, where it is in fact warranted (Day and Kincaid 1994).

11 .. Elsamahi raises this as an objection to Hacking's entity realism in (Elsamahi 1994).

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