Feats of a Mythical God: Hacking's Experimental Realism and the Success of Science

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From the first cavemen who worshipped the elements as deities to the Pre-Socratics who believed that all things came from one substance, on up to Darwin and Einstein, humanity has divined the nature of its world through a mixture of the observed physical world and the unobservable, unprovable theories that explain that world. Now, man has delved deeper into the truths of his universe than ever before, and questions about this epistemological venture must take center stage. As science becomes more and more dependent on indirect instrumental observation to explore the properties of the non-obvious world, the reliability of those instruments, the things they act on, and the very theories which explain both of these are called into question. Ian Hacking argues in his book *Representing and Intervening* that we are justified in believing in those unobservable, theoretical entities that we have used to manipulate the world, but not in the explanatory and predictive theories we craft about them (Hacking, 1983). The soundness of this argument has been repeatedly called into question, and with it, the nature of all scientific realism, and perhaps the reliability of all our epistemological claims. As Hacking and others rely solely on the field of physics to provide ammunition for their debate, a novel approach to experimental realism may be attained by examining the role of theory and experiment in another scientific discipline, biological genetics. Genetics provides an example through which Hacking's experimental realism may be tried, both by relating the philosophical argument and to actual scientific endeavor, and also by providing grounds to inquire

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into the very nature of the abductive reasoning employed by Hacking as well as other realists.

In order to properly understand the role of theory and experiment in science, we must first explore the concepts behind Hacking's arguments. Prior to Hacking, most of the focus of the philosophy of science lay on the nature of theories and the overall reality of these predictive and explanatory ideas. However, as Hacking points out, science is performed in a laboratory rather than an armchair: "No field in the philosophy of science is more systematically neglected than experiment. Our grade school teachers may have told us that scientific method is experimental method, but histories of science have become histories of theories" (Hacking, 1982, p. 154). In response, he proposes, and with good grounds, that the philosophy of science must deal directly with the actions of laboratory scientists and the mind-sets that guide them as they make scientific inquiry.

Upon inspection of the actual laboratory work, Hacking is led to conclude that the effect of experiment is to create in the world novel phenomena, which do not exist in a pure state of nature. Through these phenomena, scientists are able to explore the world and the entities in it, using one thing (in his favorite example, an electron) to act on another, much as one might use a stick to explore the contents of a hole in the ground. Hacking refers to this as interfering, and this is critical to his experimental realism. He argues that if we can use one entity to interfere with another, then the former manipulated entity must exist. The existence of the affected entity remains uncertain, but the use of the causal properties of a thing to affect another thing assures us, according to Hacking, that there is a thing to which those properties belong. To continue the stick-and-hole metaphor, if we use the stick to poke what we think to be an animal in the hole, we may elicit a hiss. While this may lead us to believe that a snake is in the hole, we cannot yet be sure. However, because we used the stick to poke something (use of a causal property), and created a novel phenomena (the hiss) with stick, we are justified to conclude authoritatively that the stick itself exists. The same is true of an electron, argues Hacking; when we use an instrument to isolate the spin of an electron and affect a current with that spin, producing a novel result, then we may safely conclude the existence of the electron as an actual entity (Hacking, 1982). Prior to using the causal properties of a theoretical entity to interfere with the world, we cannot be certain that there is something there; however, with interference comes certainty, and thus, entity realism (Hacking, 1983).

Having established how we may be realists about the entities that our theories concern, it remains for Hacking to elucidate the critical difference between theories and entities that makes the one a case for agnosticism and the other a certainty. The answer is simply a reiteration of his earlier points: theoretical entities may be manipulated in an experiment ('experimented *with*' according to McKinney, 1991) to affect other entities, but an explanatory framework can never truly be used to interfere and produce novel phenomena. Hacking recognizes that scientists do use theories in creating instruments that employ a causal property of an entity; however, he believes this use to be purely instrumental. That is, scientists might employ theories in creating their experiments, but in doing so they are not committed to the reality of those theories. To make this clear, he recalls the electron in S.S. Schweber's Penning trap, which contains an electron in a definite space. Schweber created the trap, which uses electrical and magnetic fields to hold an ion within a confined chamber, based on the early conception of the electron's charge interaction with those fields. Hacking states: "Everything they did was planned according to and can be explained by the prerelativistic theory of the electron. It is not clear that it can be done otherwise. For those purposes, that old account is better than any other" (Hacking, 1988). Here the scientists utilized a predictive theory that explains certain aspects of an electron, but which is currently rejected. They did so knowing full well that the theory was not strictly true, but instead was a convenient fiction that allowed them to work with certain causal properties of the electron successfully. The ability of scientists to switch amongst theories according to whichever best suits the occasion shows, according to Hacking, that we need not believe in the truth of those theories; in fact, we may flat out reject them. Only the successful use of an entity to interfere with reality and create a novel phenomenon assures us that we have been justified in believing in that entity's existence.

In saying that we are justified in believing in a theoretical entity when we use it to interfere with the world, Hacking relies on the idea that experimenters believe in the existence of entities bearing the causal properties they seek to use when they build their instruments. How else could they expect to achieve a result? However, as Resnik points out, this argument is abductive in nature, using the successful use of believed-in causal properties to justify the initial belief in them. In this way, Hacking essentially states that the best explanation for the success of instrumentation using certain causal properties is the existence of the theorized entities which have those causal properties, and therefore, "his [Hacking's] argument for experimental realism bears a strong resemblance to other abductivist arguments for realism, such as the infamous success of science argument," (Resnik, 1994, pp 403). In this kind of argument, the success of science in predicting and creating novel phenomena is said to be best explained by the theories of science approaching truth; we are therefore justified in tentatively accepting our theories as being approximately true (see, e.g., Musgrave, 1988). The actual reliability of these arguments is itself in question, but first, their relation to Hacking's arguments must be explored.

Resnik's charge causes grave difficulties for Hacking, who himself decries abductive arguments as unreliable, because they assume the truth of a deduced cause based only on results which could, in fact, be the product of coincidence. In *Representing and Intervening*, Hacking discusses C.S. Peirce, the originator of abductive argument discussion, saying, "by the end of his life he attached no weight at all to 'inference to the best explanation.' Was Peirce right to recant so thoroughly? I think so" (Hacking, 1983, p. 52). Clearly, he puts little weight on abductive arguments in general, and on Success of Science arguments in particular, as he discusses slightly later in the book. Likewise, he believes that inference to the best explanation allows for *ad hoc* alteration in order to 'preserve the phenomena' in theories (Hacking, 1989). How, then, does Hacking defend himself against the charge that his own appeal to the existence of interfering entities is abductive as well? He defends himself against this attack, which seems quite damning, by claiming that the causal properties of the interfering objects used in experiments are low-level 'home-truths' which do not rely on vast theoretical frameworks (Hacking, 1982). However, this is not entirely clear.

First, it may not be possible for Hacking to escape the theoretical framework he seeks to avoid at all. Rothbart and Slayden attempt to defeat Hacking by showing that theory is important in creating instrumentation, and that reliance on 'home-truths' is insufficient for an experimenter seeking to utilize a theoretical entity. "Within the use of modern instruments, theoretical models are needed to secure the signal's reliability, to define the complex causal sequence of physical events from specimen/instrument to the readout, and to access the specimen's properties" (Rothbart and Slayden, 1994). Resnik and Pierson also affirm this idea, stating that we cannot be justified in believing in a theoretical entity without believing in a theoretical framework to sustain it. Hacking wishes to avoid this by appealing to Putnam's views on reference (Hacking, 1982), which state that there are five distinct ways of referencing a thing. Under this scheme, the existence of a real entity which we reference is different from the common conceptions, or stereotypes, that we hold about the thing. Thus, though we have ideas and theories about what an electron is, these are distinct from the actual physical electron, and therefore, the entity is separable from the theory surrounding it. Resnik retorts with the fact that experimenters have knowledge of the core theories surrounding the things they are dealing with, and these theories are critical in their interpretation of what occurs in their instruments, and therefore their actual construction of the instruments themselves. Schweber, for example, must have used the prerelativistic theories of the electron in the construction of the Penning trap, as those theories provided the only guideline he had for how an electron should behave. As we do not have direct access to theoretical entities, our theories are necessary to interpret what we do have access to as resulting from those entities. This is a seriously more substantial account of the way experimenters use theories than the instrumental way Hacking assumes. If this is true, then Hacking is forced to recant his piece-meal realism and either accept full-blown realism or reject entity realism as well.

In addition to this worry, even should Hacking be successful in sustaining the distinction between home truths and theories, he may still be obligated to admit to abductive reasoning. In arguing for the reality of entities observable via instrumentation, Hacking states that we may reliably believe in those things which we see through many different instruments using many different physical processes (Hacking, 1982). It is so unlikely as to be ridiculous, then, that all these instruments should turn up the same results and be wrong. However, Pierson and Reiner point out that this is simply using the explanatory power of the entities being real to conclude that the entities are real, and "reliance on explanatoriness as a mark of truth is the weakness of IBE (Inference to the Best Explanation)" (Pierson and Reiner, 1995). In the laboratory, we only have access to certain things, such as readouts, rather than the entities themselves, and therefore we are forced to rely on IBE to say that these readouts reflect the true entities. A more charitable version of this argument is given by Resnik, who states that even the home-truths Hacking argues for must be grounded in a general causal nexus, and the assumption of this nexus is what leads to this being an abductive argument, just as is Musgrave's Ultimate Argument (Resnik, 1994). Thus, though 'home truths' rely on a nexus much simpler than that assumed by full theories, Hacking is confronted with the same charge if abductive reasoning regardless. To further compound the matter, even should a causal nexus be assumed, it does not follow that certain causal properties that can be used to interfere with the world are necessarily linked to actual theoretical entities as postulated. It is a further IBE to suppose that the properties believed to be of an electron are actually of a single entity; this has occurred falsely in the history of science already, as will be seen below.

With such damning arguments against it, how can entity realism survive? Several alternative versions of entity realism are put forth in the literature, such as the version of realism set forth by Cartwright, which concerns certain theoretical entities as the causes of events. Cartwright holds that because we can observe effects, we can then infer causes. Causal laws, however, are not real, because they either do not accurately assess real situations, or else ceteris paribus conditions lower their usefulness in real world situations (Cartwright, 1983). Baird and Faust believe that instruments may use theories to assist them or provide an impetus to their creation, but in fact are in and of themselves independent elements of scientific knowledge, utilizing real entities to create real results (Baird and Faust, 1990). This is similar to Hacking, but holds scientific instruments as essential pieces of knowledge in addition to the entities they utilize. McKinney holds with Hacking that entities may be separated from their theoretical framework and believed in independently of theories, but believes that manipulation and interference are neither necessary nor sufficient conditions for entity realism. However, in all these instances, as in Hacking's own writings, all examples are confined to the study of physics, where complex machines are used to manipulate what are believed to be corpuscular unit-entities to create effects on other entities. While this is quite convenient for discussing the distinction between entities and theories, the sciences present a wide array of situations where this distinction is not so clean. In biology, what constitutes an entity and what constitutes a theory are not nearly so clear-cut as in physics, and as such, experimental realism may take on a different light after application to those areas.

The base unit of biology and evolution, according to many prominent thinkers, is the gene (Dawkins, 1976). Genes also provide us with a premiere example of a theoretical entity, and a great amount of theory surrounding it. In his book *Explaining Scientific Consensus*, Kyung-Man Kim examines the early controversies of genetics from the perspective of a sociologist of science; his text, however, also provides great insight into the nature of entity realism. As Darwin crafted the theory of natural selection, a critical necessity was placed on the idea of heredity. Natural selection depends heavily on the idea that species change through variations accumulated over time from generation to generation. However, Darwin did not possess a working theory as to how heredity acted. Later he proposed that the traits of ancestors blended in the creation of offspring, and this resulted in the variation observed. His cousin, Francis Galton, seized upon this idea and developed it to the point where all the traits of an individuals ancestors blended over a mathematical curve affected by a constant of regression to a proposed species norm; this, he called 'biometrics' (Kim, 1994). Gregor Mendel, however, had proposed a method of heredity wherein individual units of trait selection (genes) acted with each other following certain discrete rules to determine the eventual traits of the being. These laws, according to Mendel, consisted of: a) character segregation, the idea that genes do not blend in a zygote, but instead remain as inviolate units; b) independent assortment, also called recombination, the idea that genes for different traits move independently of each other and are unaffected by each other; and c) dominance, the idea that one version of a gene will prevail over another version in deciding the ultimate characteristic of the final being. At this stage, both Mendelian genetics and biometry were simply theories, and genes themselves were what Hacking refers to as hypothetical entities; that is, theoretical entities which have not yet been used to interfere with the world and therefore do not count as real.

To resolve the biometry-Mendelism debate, as Kim explains in much greater detail than can be afforded here, experimentation was run to observe the actual nature of heredity. In these experiments, individual members of a species with certain characteristics were bred together, and then their offspring bred together, and the resulting characteristics were observed. Here, Hacking would tell us that genes as entities were being experimented *on*, rather than *with*. The results of these tests showed that in fact, heredity seems to follow a nature more in line with Mendel than with biometry; this lead to the acceptance of Mendelian genetics as the correct theory of inheritance.

According to McKinney, this experimentation alone, as it was highly controlled and repeated, provided reasonable grounds for belief in the existence of genes (McKinney, 1991). Hacking, too seems to assert a similar notion; while he tells us that we are not yet justified in believing in the existence of entities that have merely been experimented on, he also states that believing in these entities is precisely what scientists do, and what leads them to manipulate entities (Hacking, 1982)! Of course, Hacking has clearly asserted his belief that entity realism is unfounded until *after* the entity is used to intervene with nature. One then must ask: how can he escape the trap of Success of Science arguments when he states that the unproven beliefs of scientists are proven to be true when they are used? This seems to mimic the ideas of Musgrave, that we are justified in believing in our theories because the theories produce success (Musgrave, 1988). However, the subsequent history of genetics casts a more light on the situation.

After Mendelian genetics became accepted, the depth and breadth of the idea could be properly explored. Almost immediately, complications arose. Upon looking at nature, it became apparent that some genes coding for opposing traits failed to express clear dominance. In these examples, heterozygotes did, in fact, show a blending of characters, similar to the assertions of biometry. In these cases, the concept of dominance had to be revised. However, Mendelism maintained its hold on biological thought because of the presence of the two other factors, character segregation and independent assortment. Independent assortment, however, also fell to empirical evidence when it was observed that certain genetic traits traveled together: i.e., that in some cases, the genes for hair color and eye color seemed to always travel together. This required a further revision of Mendel, where genes were stated to exist on chromosomes, and different traits might be carried on the same chromosome, resulting in an assortment which was not entirely independent. Further, character segregation was challenged by the fact that certain phenotypic traits seem to involve a greater degree of variation than should be possible in the simple one-to-one Mendelian ratio. To combat this, biologists proposed the idea that multiple genes may combine their effects to create a phenotypic trait. At the end of the day, however, it appears that we have thrown out all three of the requirements for Mendelism, yet scientists still assert the existence of genes. How can this be?

Hacking is only more than happy to answer this question. It is because, he says, the entities are real, but the theories behind them are not; these are just useful fictions employed to explain why the entities behave as they do, and do not compose the 'home-truths' of the genes. However, if the three criteria of character segregation, independent assortment, and recombination, the very things that initially defined genes, do not count as 'home-truths', what does? According to our theories of how genes work, we have made machines which insert various sequences in various areas in a genome in order to produce a desired effect, and this is surely what Hacking refers to as 'interfering.' We have, in fact produced novel phenomena through these means.

For example, scientists have taken created glowing tobacco plants using firefly DNA, and sterile, genetically engineered salmon are being created which reach twice the size of normal salmon in half the time. These real world results are produced by manipulation of genes and the use of them to interfere with the world to produce novel phenomena; scientists use the causal properties ascribed to genes to experiment *on* phenotypic variation and interspecies transference. Scientists are capable of observing chromosomes through microscopes, watching the movement of RNA and DNA, and discerning the role of these molecules in the creation of proteins. However, no one has ever 'observed' a gene. Areas of DNA code for proteins; this we can see. Genes, however, are supposed to code for traits. Despite our ability to 'interfere' with genes (that is, to use genes to experiment on other things), it is not apparent that these theoretical entities actually exist. It is the fact that we can observe changes in traits when we alter different parts of certain areas of DNA that leads us to believe that there are distinct stretches that code for certain traits. Even this is called into question with the idea of polygene traits. Manipulability of genes does not give us grounds to believe in them; rather, we believe in genes because they are the best explanation for the results we observe when we manipulate. This, then is an abductive inference to the best explanation argument. Though Hacking wishes to deny it, he has fallen into the same camp as Musgrave.

But what's wrong with IBE? Abduction has always existed, and its uses are nearly infinite. Nearly all of our historical claims are IBE claims, as are "observational properties of ordinary physical objects (such as stones or tables)," (Niiniluoto, 1999, p. 442). "The fact that Napoleon Bonaparte once lived is not anymore 'suspectible of direct observation' (than theoretical entities)," states Niiniluoto, "but we believe it because 'the effects (such as the histories, the monuments, etc.) are observed'" (Niiniluoto, 1999, p. 442). This argument is somewhat suspect. As Hume first pointed out in his argument against induction, simply because we rely on a certain method of reasoning frequently does not make that reasoning sound. Perhaps we are forced to make abductive judgments about things of which we can have no direct observational evidence, but this does not necessarily entail our belief in our abductive judgments as True. Abduction relies on an indirect method of reasoning, which states that the best explanation that can be thought of by us is most likely the correct one. This may be a useful tool to guide our actions, but it is not logically sound. The idea that mankind's best explanation is the correct explanation hinges on the idea that man *knows* the correct explanation, which in many (if not all) cases is not true. The history of genetics shows us that biometry, the best theory available to Darwin, was completely false, not even approximating truth. In turn, the initial premises of Mendelism were later found to be false, though they provided the best explanation available at the time for the phenomena. This illustrates quite clearly the problems of abduction, and any argument that relies on abduction is susceptible to the same very real possibility of falsehood. Fallibilism cannot account for this, as underdetermination implies a nearly infinite amount of alternative explanations for data. Even Novel Predictive Success, which does not come into play until after an IBE judgment is made, is subject to underdetermination, as Stanford shows. The realist, then, has no recourse but to pure abduction, and pure abduction, while useful, is unreliable in finding the Truth.

Where, then, does experimental realism stand? It is clear that abduction and IBE are essential for entity realism, and that they are neither necessary nor sufficient grounds for true belief. However, this does not entail a complete failure on the part of experimental realists. Baird and Faust state of the cyclotron, "the beam of accelerated ions could be routed—on demand—into the atmosphere, where it produced a dramatic display" (Baird and Faust, 1990, p 169). Thus, our belief in a theoretical yet logically unreliable entity produces a real world result which is readily observable. In the same vein, genetic engineering produces real results; that is, when we tamper with 'genes', we really produce fungus-resistant strains of corn, for example, or fruit flies with extra legs. In light of these scientific successes, complete belief in our theories and entities as corresponding to the True nature of the world is not necessary. The fact that we do believe in these entities and the ability to alter that belief with new data has allowed us to make great progress, at least from a utility standpoint, and this cannot be ignored. While we need not conclude that theoretical entities exist, the observable results of those entities remain, and our tentative treatment of those entities as real is what makes that success possible. Thus, as genetics has shown, Hacking's experimental realism is not justified; use of a causal property does not entail belief in that entity's existence. Abduction, such as Hacking uses, is not invalid and unreliable in determining the correspondence of what we believe and what is True. However, it allows us to act on an entity we do not believe in the True existence of in a realist manner (that is, we act upon them as though they were real while acknowledging that those entities may not actually refer) and still produce real results. Thus, though the entities we make, our modern deities of science, may be nothing but myth, we may safely still reap the benefits of our allegiance to them.

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