Strings and Stringency

A review of Richard Dawid's *String Theory and the Scientific Method*

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To paraphrase Steven Weinberg and misquote John Cleese, 'what have philosophers ever done for us?' Weinberg, a Nobel Prize-winning physicist, dedicates an entire chapter of his *Dreams of a Final Theory* to a diatribe against philosophy. At his most conciliatory, he claims that philosophy is not *wholly* useless to physicists, given that 'insights of philosophers have occasionally benefited physicists, but generally in a negative fashion—by protecting them from the preconceptions of other philosophers.'

Weinberg's sentiments are echoed by several high-profile physicists, Neil de Grasse Tyson and Stephen Hawking among them. The evidence is surely stacked in their favour, they argue. Physics and philosophy do have overlapping magesteria—both are in the business of investigating the world, of telling us what is out there and what principles govern what is around us. But physicists are beholden to the *scientific method*, an evidence-based heuristic with incomparable success. We build bridges and fly planes and work on computers because it was Newton, Einstein and Feynman who got things right, not Aristotle, Descartes or Kant.

This is a caricature, to be sure, but there is a form of this intuition that pervades the physics community. So powerful is the trust that physicists have traditionally had in evidence-based reasoning that it formed the basis of one of the most prominent philosophical movements of the twentieth century. The Logical Empiricists, whose most famous member, arguably, was Rudolf Carnap, were the direct descendants of the Logical Positivists and Moritz Schlick's Vienna Circle in the mid 1910s. At the heart of their philosophy, was the doctrine of verificationism—that a sentence is only meaningful either if is vacuously true, or if it is possible, in theory, to verify it empirically. In one fell swoop, metaphysical speculation about the unobservable was consigned to the history books. Metaphysical claims suffered a fate worse than a fate worse than death. They were not even false; they were *meaningless*.

Karl Popper, a figure who was tantalisingly poised at the fringes of the movement, reacting to the doctrine of verificationism as a criterion for meaning, developed the doctrine of falsificationism as a criterion for being *scientific*. On his view, a theory would only qualify as scientific if it made claims that could be falsified when confronted by the tribune of experience. Scientific theories, according to Popper, were not the sorts of things that could be verified. No, the best scientific theories were the ones that had survived repeated attempts to be falsified. Due, in part, to his reverence for physics, his view has become the default characterisation of the construction of a scientific theory. It presents physics as unaffected by dogma, an endeavour of the purest spirit of discovery which defers to no one other than Nature.

If this is what modern philosophy says, why is Weinberg so disenchanted with it? The answer is that modern philosophy does not say this any more. Logical empiricism

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collapsed in the early sixties; verificationism turned out to be untenable as a criterion for meaning, based, as it was, on two arbitrary distinctions; one between the observable and unobservable, the other between necessary truths and contingent ones (or, to use Kant's terminology, the distinction between *synthetic* truths and *analytic* ones). As a result, a priori metaphysics broke out of the empiricist shackles and continues, to this day, with great vigour. It is to this tradition, and its links to pre-verificationist schools of thought that Weinberg directs his criticism.

Why should we bother about the scientific method? After all, not even Popper claimed that *only* scientific statements told us meaningful and true things about the world. But there is more to the scientific method than merely telling us true things about the world. It *reliably* tells us true things about the world. I could easily guess the results of a few cricket matches and get them right. But unless I can demonstrate that I adhere to some reliable inference mechanism (perhaps I have a direct contact with an oracle, or have travelled back in time; not all methods of reliably generating true inferences need to be scientific), I cannot be relied upon to make accurate predictions. But, armed with the scientific method, physicists can, and indeed do make accurate predictions all the time.

Much ink has been spilled trying to distil from the amalgam of mathematical, physical and methodological techniques a core of practices that unequivocally and uniquely constitute the scientific method. But everyone appears to agree that confrontation with experiment and experience is an unassailable part of it. How devastating would it be if we got to a point where we could no longer test, directly or indirectly, through their unique predictions, our most popular contemporary theories of physics? That we have actually got to this point is the scandal that has been at the heart of theoretical physics for the last forty years.

String theory, a candidate theory for a unified theory of everything ('everything' to a physicist refers to the four fundamental forces, electromagnetism, the strong and weak nuclear forces and gravity) has been the most actively researched theory in theoretical physics for the last twenty years. Yet it makes no novel predictions of observable data. And cannot be directly tested by any refinement of our current collider technology. This is far from ideal. If we have lost one of the fundamental pillars of the scientific method, are we forced to give up on it? What becomes of the hegemony that science has on reliable inference?

Richard Dawid, a string-theorist-turned-philosopher-of-science, proposes a radical shift in our understanding of what it is for a theory to be scientific in his *String Theory and the Scientific Method*. He contends that the scientific method, if properly re-evaluated, can survive the shift into the post-empirical era. To many, 'post-empirical science' sounds like a contradiction in terms. Dawid constructs an elaborate programme of non-empirical theory assessment to argue that this is not the case. On top of that, he makes the case that string theory can be confirmed on the basis of non-empirical evidence. The million-dollar question is, does it work?

No. It does not. But, as with many failed philosophical projects, the reasons for its failure are instructive and illuminating. Dawid's programme of non-empirical theory assessment is the subject of the first half of the book. His response to critics who claim that string theorists' faith in string theory is unfounded is to set up string theory as the only conceivable theory which satisfies certain physically reasonable constraints.

It is theoretically possible for any finite set of data points (and, remember, we will only ever have a finite amount of experimental data) to be accounted for by an infinite number of different theories, many–indeed, infinitely many–of which will be mutually incompatible. This, in a sentence, is known as the problem of *scientific underdetermination*. Every new data point, however, limits this underdetermination, by ensuring that a number of the candidate theories that could account for the data earlier no longer do so. In this sense, experimental data serves to reduce the number of theories that are compatible with data (such theories are said to be *empirically adequate*). Traditionally, it is experimental data that is relevant. But what if, asks Dawid, there were some suitably stringent non-experimental, non-empirical data that could reduce the number of viable empirically adequate theories? Surely that would call for an expansion of the domain of the scientific method.

For Dawid, three mutually reinforcing arguments give us a way of eliminating viable theories. In fact these arguments are so restrictive that they eliminate all alternatives to string theory! The first, the No-Alternatives argument is the most important, and establishing its validity is the central goal of the project. According to this argument, we should take the inability of scientists to come up with alternative theories to a particular theory as evidence that there are likely to be few or no alternatives to that theory. If this is the case, then scientists should have a high degree of trust in that theory. One might object immediately, and say that this is just as likely to be evidence that scientists are not ingenious enough, or that the problem is just beyond their cognitive abilities to solve.

To block this, Dawid offers the Meta-Inductive Argument and the Unexpected Explanatory Coherence Argument. The former places string theory in the tradition of the research programme of quantum field theory, the most (experimentally) successful theory of matter in history. If it can be established that a theory is in the same research programme as a highly successful series of past theories, then one might take their past success as evidence of the viability of the research programme as a whole. This would be license the belief that there are no alternatives to string theory because it is the correct theory, rather than because scientists are not skilled enough to find alternatives. The Unexpected Explanatory Coherence Argument states that if a theory is developed in order to explain one kind of phenomenon, and ends up providing an explanation of the mechanism of an unrelated phenomenon, then that increases the likelihood that we have found the right theory. In the same way that prediction of novel phenomena counts in favour of a particular theory, this unexpected coherence counts in favour of the proposed hypothesis. The punch-line is that string theory is the theory of fundamental physics which satisfies these criteria.

In speaking of the likelihood that a theory is true, it seems like we are making a quantifiable claim, something along the lines of 'There is a 96% chance that this is true.' There is a formalism, ubiquitous amongst philosophers of science and epistemologists, for making such claims. Known as Bayesian Confirmation Theory, named after the eighteenth century Presbyterian minister and statistician Thomas Bayes, it forms the basis for Dawid's claim that string theory is confirmed. Incidentally, the term 'confirmation', in this context has a very specific meaning. In order to count as being confirmed, a theory only needs to be shown to be more likely after the discovery of a piece of evidence than it was before. If I was 60% sure that a theory was true, and then discovered a piece of evidence that raised my confidence in its truth to 61%, then that would count as confirmation, in the Bayesian sense. To bring this usage closer to the everyday sense of 'confirm' to mean something like 'establishment of some measure of closeness to the truth or correctness of', it would need to be the case that our confidence in a theory jumped significantly on presentation of some evidence.

This is, unfortunately, where Dawid's programme veers wildly off the rails. He goes through a meticulous construction in order to demonstrate that Bayesian Confirmation Theory is the appropriate mathematical machinery for his project. Even if we were to grant Dawid this, we would need it to be the case that it generated non-negligible confirmation. And (as can be demonstrated easily) the numbers just do not add up.

The level of confirmation that Dawid's programme provides us with, for string theory, and indeed any other theory with no empirical predictions, is wholly negligible, even if it is non-zero. And a little thought reveals that this is only to be expected. Our scientific theories are, after all, a complex interplay of theoretical considerations (for example that they should be consistent) and experimental predictions. Few people would deny that theoretical considerations play a role, but it seems highly unlikely that they play *anywhere near* as important a role as experimental ones do. Dawid's programme inadvertently reinforces that intuition.

Much like Weinberg, Dawid wants the scientific method to remain unchallenged in its authority to generate truth. His reason, though, is more tendentious than Weinberg's. Ultimately, Dawid can be read as arguing for at least one of three increasingly weakening claims—firstly that string theory is the final theory (that Weinberg dreamt of), secondly, that string theory is a scientific theory and thirdly, that string theory is worth pursuing actively. If he establishes either of the first two claims, then Dawid establishes the third one automatically. The first half of the book argues unsuccessfully that string theory is a true scientific theory. Even if Dawid had been successful there, he would still not have been able to claim that he had established that string theory was the final theory. In the rest of the book, Dawid turns to a discussion of whether string theory can claim to be the final theory, and, if so, what effect it has on our metaphysical picture of what the world is actually like. It is at this stage, once shorn of the need to establish a concrete position on string theory, that the discussion becomes more philosophically involved and illuminating. Dawid is at pains to stress that his programme is not intended to replace experimental data as the gold standard for theory assessment, merely to provide an effective substitute in its absence. As such, it allows for a discussion of issues related to scientific realism, a discussion which does not even get off the ground if there is no way to argue for the physical relevance of a theory.

Dawid may not have provided a justification for string theory research, but he has certainly opened the door for an important field of philosophical research on the epistemology of theory confirmation in the absence of empirical data. At least philosophers now definitely have an answer to the question 'what have physicists ever done for us?'