Improve Popper and Procure a Perfect Simulacrum of Verification Indistinguishable from the Real Thing

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Abstract
According to Karl Popper, science cannot verify its theories empirically, but it can falsify them, and that suffices to account for scientific progress. For Popper, a law or theory remains a pure conjecture, probability equal to zero, however massively corroborated empirically it may be. But it does just seem to be the case that science does verify empirically laws and theories. We trust our lives to such verifications when we fly in aeroplanes, cross bridges and take modern medicines. We can do some justice to this apparent capacity of science to verify if we make a number of improvements to Popper's philosophy of science. The key step is to recognize that physics, in accepting unified theories only, thereby makes a big metaphysical assumption about the nature of the universe. The outcome is a conception of scientific method which facilitates the criticism and improvement of metaphysical assumptions of physics. This view provides, not verification, but a perfect simulacrum of verification indistinguishable from the real thing.

Karl Popper, falsification, verification, metaphysics of physics, theory unity, scientific progress

1 Popper's Falsificationism

According to Karl Popper, science cannot verify its theories empirically, but it can falsify them, and that suffices to account for scientific progress. Science proceeds, according to Popper, by proposing empirically falsifiable conjectures which are then subjected to a ferocious barrage of attempted empirical falsification. Sooner or later, such a conjecture will be empirically falsified. When this happens, scientists are forced to think up something better, a testable conjecture (a) which successfully predicts all the phenomena its predecessor successfully predicted, (b) which successfully predicts the phenomenon that refuted its predecessor, and (c) which successfully predicts some phenomena not predicted by its predecessor. The new theory is then subjected to the same barrage of attempted refutations.

And that is how science advances, by proposing and falsifying theories of ever greater empirical content and predictive and explanatory success. But however empirically successful a scientific theory may be, it remains irredeemably a conjecture. Its absolute conjectural status is not altered one iota by its empirical success.

Popper is prepared to concede that a theory that has survived severe attempts at refutation, may be held to be "corroborated", but he is nevertheless adamant: a theory corroborated by evidence is not thereby verified, not to any degree of probability greater than zero.

2 Our Belief in Practice in Empirical Verification

It is this aspect of Popper's philosophy of science that probably seems most unsatisfactory to those scientists and philosophers of science who cannot accept

Popper's basic position. It just does seem to be the case that in science we do have verification of theory by evidence.[1]

There are, of course, those famous instances of verification of theory in the history of science, such as the verification of the wave theory of light by the observation that there is a spot of light in the centre of the shadow cast by a small disk, or the verification of Einstein's theory of general relativity by the observation that light from a distant star is deflected by the predicted amount when it passes close to the eclipsed sun. But in addition to these, there is that mountain of perhaps more humdrum verified results that no one doubts for a moment: physical properties of matter; chemical properties; molecular and atomic constituents; anatomical and physiological features of the human body; basic properties of the earth, the moon, the other planets; even basic features of the milky way and other galaxies. There is a wealth of law-like knowledge here, based on countless experiments, measurements and observations, that no one seriously doubts. It seems absurd to hold that all this securely verified scientific knowledge is just as conjectural as the wildest speculation of the theoretical physicist, cosmologist. or lay person.

In practice, we recognize that there is a sharp distinction between verified scientific knowledge on the one hand, and conjecture, guesswork and speculation on the other. We trust our lives to this distinction. When we cross bridges, fly in aeroplanes, and take modern medicine, we do so, entrusting our lives to the reliability of those verified scientific results which declare: the bridge will not collapse, the aeroplane will not disintegrate in the air, the medicine will not poison. Popper's philosophy of science cannot, it seems, account for this decisive distinction we draw in practice between verified result we entrust our lives to, and speculation we have no confidence in whatsoever. The first may be empirically "corroborated", while the second may lack all corroboration but, according to Popper, corroboration adds nothing whatsoever to the trustworthiness of a law-statement or theory.

In practice we believe in empirical verification, it seems. Indeed, we are prepared to entrust our lives to it. But no one can justify such a belief. All attempts to solve Hume's problem of induction have failed.[2] Our belief in practice in empirical verification is pure bad faith. We live our lives as if we do believe in empirical verification but we can give no account whatsoever as to how it is possible.

3 The Perfect Simulacrum of Verification

I have a suggestion as to how we may be able partially to escape this position of intolerable bad faith. Improve Popper's philosophy of science somewhat, and one has a doctrine which provides, not authentic empirical verification, but something that is indistinguishable from it. We have, not empirical verification, but a perfect simulacrum of it. How would we ever, in practice, know the difference? Only the philosopher would declare: "I should perhaps warn you that what you take for authentic empirical verification is only a flawless, faithful, utterly accurate simulacrum of it".

On the other hand, given that this simulacrum is so utterly flawless, faithful, and accurate in every detail, is not it good enough? Why would anyone want anything more? Is not asking for more, in the circumstances, a bit churlish? We shall see!

I should be clear, at the outset, what it is that I claim to establish in this paper that is original and important. I, like others, have criticized Popper's philosophy of science before,[3] and I have put forward what is, I claim, a much improved view: *aim-oriented empiricism*.[4] What I have not done before is demonstrate that six successive *improvements* to Popper's falsificationism transform that doctrine into aim-oriented empiricism, and that doctrine provides a perfect simulacrum of verification of theory by evidence – something which falsificationism singularly fails to do. *If* aim-oriented empiricism is correct, and that, admittedly, is quite a big if, then there is in physics, and in science more generally, a perfect simulacrum of verification of theory by evidence which matches actual scientific judgements about verification of theory by evidence almost perfectly, and which, furthermore, provides a justification of the view that physics has made, and continues to make, real progress in theoretical knowledge about the nature of the universe despite the fact that physics progresses from one false theory to another.

That strikes me as a quite remarkable result: improve Popper's falsificationism, and one arrives at a position that can do justice to aspects of science that Popper singularly fails to do. Justice is done to the manner in which science seems to verify theory by evidence, to such an extent, indeed, that we are prepared to trust our lives to the apparent verification. And justice is done to the view that physics has made, and continues to make, real progress in theoretical knowledge about the nature of the universe even though it advances from one false theory to another.

There is a further crucial point. The six *arguments* in support of the six improvements to falsificationism are all arguments that should be found to be convincing by those sympathetic to Popper's philosophy. They are, in other words, characteristically *Popperian* arguments.

Thus one argument amounts to the clarification of an excellent point Popper made about simplicity in science which Popper himself acknowledged he expressed in only a vague and unsatisfactory way. Another involves acknowledging, and responding to, a falsification of Popper's methodology – a glaring discrepancy between what science does and ought to do, and what Popper's methodology recommends. Yet another involves making explicit assumptions that are problematic and implicit so that they can be *criticized* and thus, we may hope, improved. Another involves adopting methods which facilitate the capacity of science to subject substantial scientific conjectures to sustained *criticism*. And another results in the solution to a problem that Popper discovered, and tried and failed to solve: the problem of verisimilitude. Throughout, excellent basic tenets of Popperian philosophy are adopted: all our knowledge is conjectural; we can best learn by subjecting conjectured solutions to problems to *criticism.*

All these are highly *Popperian* considerations. They exemplify what is excellent and correct in Popper's philosophy. The improved version of Popper's philosophy of science that emerges from these considerations – aim-oriented empiricism – arises, as it were, from following the logic of Popper's own position.

In short, improve Popper for good Popperian reasons, and one arrives at a position that solves problems that Popper's original philosophy of science cannot hope to solve.

4 Serious Failings of Popper's Philosophy of Science

Inability to do justice to the fact that in science theories do seem to get verified empirically is not the only failing of Popper's philosophy of science. Much more serious is his failure to do justice to the way in which theories are merely *selected* in science, all questions about verification being ignored.

Consider any accepted fundamental physical theory, T. T might be Newtonian theory, classical electrodynamics, quantum theory, general relativity, quantum electrodynamics, or the standard model – the quantum field theory of fundamental particles and the forces between them. Whatever T may be, there will always be infinitely many rival theories that fit all available empirical data just as well.[5] In order to concoct such rival theories, all we need to do is modify T, in any way we please, for phenomena not yet observed. Let us, for simplicity, take T to be Newton's law of motion, F = ma, where F is force on a body, and m and a are its mass and acceleration respectively; and his law of gravitation, $F = Gm_1m_2/d^2$, where m_1 and m_2 are the masses of two bodies, d is the distance between them, G is a constant, and F is the force between the two bodies due to gravitation. One rival to this theory, that fits available data just as well is the following: everything occurs as Newton's theory asserts up to the last moment of 2050; after that date we have the inverse cube law $F = Gm_1m_2/d^3$. There are infinitely many such rival theories to Newton that, for the time being, meet with all the predictive success of Newton's theory, since there are infinitely many different times available in the future that we may take to be the date at which Newton's inverse square law abruptly becomes an inverse cube law. Even if we restrict ourselves to one specific date, the last moment of 2050 for example, there are still infinitely many rivals to Newtonian theory that fit all available data just as well, since there are infinitely many alternatives to the inverse cube law. We have $F = Gm_1m_2/d^n$, where n is any real number such that $0 < n < 2$ or $2 < n$. And of course there are endlessly many expressions that differ from $F = Gm_1m_2/d^n$, such as $F = Hm_1^pm_2^p/d^n$, where $H \neq G$, and p is any positive real number that differ from 2. Another possibility is $F = d^n/Hm_1^pm_2^p$. And there are endless further possibilities. We can, for example, postulate that gravitation becomes a repulsive force after the last moment of 2050.

Another infinity of rivals to Newtonian theory that fit all available data just as well can be procured by considering theories that change their form abruptly, not at some specific time, or not in some specific space-time region, but for some range of variables other than space and time, such as mass. Consider, for example, the following rival to Newtonian theory: everything occurs in accordance with Newtonian theory except for bodies of pure gold of masses greater than 10,000 tons adrift in a near vacuum; for these bodies, $F = Gm_1m_2/d^3$. As before, infinitely many different rivals along these lines exist, all just as successful empirically as Newtonian theory as far as available data are concerned.[6]

A further infinity of such rivals to Newtonian theory can be specified by taking, not some physical system that no one has created, and no one is likely to create ever, but rather by taking an absolutely standard experiment that corroborates Newtonian theory, that has been performed countless times, and adding some bizarre detail that ensures that this particular experiment has never been performed. For example, the detail might be: 50 grams of gold dust is sprinkled around the experiment. And the rival theory asserts: everything occurs as Newtonian theory asserts, except for the experiment with gold dust; for this experiment, what occurs obeys the law $F = Gm_1m_2/d^3$.

So far we have established that there are infinitely many rivals to any accepted physical theory, T, that fit all available data just as well as T, but which make predictions for as-yet unobserved phenomena that differ from T. It gets worse. There are infinitely many rivals to T that fit all available data *even better than* T.

Given any accepted physical theory, T, almost inevitably the empirical predictions of T will fall into four categories. There will be phenomena A successfully predicted by T; there will be phenomena B that T cannot yet predict because the equations of T have not yet been solved, although in the future they may be solved, at least approximately; there will be phenomena C that ostensibly refute T, although further work may well reveal that this is not the case (invalid background assumptions have been made, experiments have not been performed correctly); finally, there will be phenomena D that lie beyond the scope of T.

Let us now assume, in order to simplify the argument, that T is Newtonian theory. And consider that rival theory, T*, just as empirically successful as Newtonian theory (so far) that asserts: after the last moment of 2050, Newton's law of gravitation becomes $F = Gm_1m_2/d^3$. Now modify this rival theory, to form T**, so that it asserts the following. As far as phenomena A are concerned, everything occurs as T* asserts; as far as phenomena B, C and D are concerned, these phenomena occur in accordance with observationally and experimentally established empirical laws.

In comparison with T, T** has the following advantages. First, T** recaptures all the empirical success of T as far as phenomena A are concerned; second, T** successfully predicts phenomena in B that T does not predict; third, T** successfully predicts phenomena in C that ostensibly *refute* T; fourth, T** successfully predicts phenomena in D about which T is entirely silent. As far as available data are concerned, T** is better than T because T** (1) successfully predicts everything T predicts, (2) successfully predicts phenomena that T does not predict, and (3) successfully predicts phenomena that refute T.

On empirical grounds, T** is a better theory than T.

In a similar way, the infinitely many rival theories, considered above, that are just as empirically successful as Newtonian theory, give rise to infinitely many theories that are even more successful empirically than Newtonian theory.[7]

Confronted by this infinity of rival theories that fit available phenomena even better than accepted theory, one's immediate response is likely to be "These theories cannot be taken seriously for a moment because they postulate an arbitrary, wholly ad hoc, change in the laws of nature, and our universe is simply not like that". We are convinced, in practice, that the universe exhibits a certain sort of uniformity – uniformity in space and time, but also uniformity as other variables are varied, such as mass or temperature.[8] If abrupt changes in laws do occur as one varies spatial locality, time, mass, temperature (or some other variable), then this change of law occurs *for a reason*. That is, there are deeper laws that do not change, and which explain the change of more superficial law-like statements, restricted in scope.

It is worth noting, in passing, just how strong is our commitment in practice to the truth of this uniformity thesis.[9] There is a theory that fits all available data even better than Newtonian theory, or Einstein's theory of general relativity, that predicts that gravitation will abruptly become a repulsive force in ten minutes time. There is, in short, a massive amount of evidence in support of the prediction that gravitation will become a repulsive force in ten minutes time. Despite this, we do not believe it for a moment. Why not? Because in practice we do not for a moment take seriously the possibility that the laws of nature will abruptly change. We do not take seriously, in other words, the possibility that the thesis of uniformity might be false.[10]

This uniformity principle is a metaphysical thesis about the nature of the universe in the Popperian sense that it is not empirically falsifiable. If we do detect empirically, apparent ad hoc, inexplicable changes in laws, L, there must always be the possibility that there is some underlying law which does not change, and which can *explain* the apparently ad hoc, inexplicable changes in L. We can never decisively refute empirically this possibility of underlying uniformity; the thesis of uniformity is thus unfalsifiable, and therefore, in Popper's sense, metaphysical.

I claim that the instinct to dismiss empirically successful but seriously ad hoc theories on the grounds that they clash with the metaphysical thesis of uniformity is entirely correct. This is indeed the proper reason for rejecting these infinitely many empirically successful, ad hoc theories. In our lives, and in engaging in scientific research, engineering, medical research, and other specialized activities such as medicine, plumbing, bridge building, architecture, electrical repairs and so on, we in practice take the thesis of uniformity for granted, and reject hypotheses and theories which clash with this thesis, however empirically successful they might be. But this is not a reason that Popper can deploy. We are considering what philosophers of science call "the context of justification" or "the context of acceptance"[11] – the context in which it is decided what theories are to be accepted as a part of scientific knowledge. If infinitely many theories, empirically more successful than the theory we accept, are rejected – or not even considered – solely on the grounds that they all clash with the thesis of uniformity, then this thesis has the status of scientific knowledge. It must be held to be as secure an item of scientific knowledge as anything theoretical in science can be – since it is upheld in scientific practice in such a firm way that an infinity of theories empirically more successful than an accepted theory – quantum theory perhaps, or general relativity – are rejected on the sole grounds that they clash with this thesis of uniformity. But Popper cannot hold that the thesis of uniformity is an item of scientific knowledge. As we have seen, this thesis is a *metaphysical* thesis, and thus, according to Popper's criterion of demarcation, a thesis that is to be excluded from science – from scientific knowledge at least.[12] Popper is himself quite explicit on this point.[13]

What reasons can Popper give for accepting T – the theory scientists in fact accept – and rejecting all of {T**}, the infinitely many ad hoc rivals to T that fit all available data better than T? This question poses a very serious problem for Popper's entire philosophy of science. For the methodology of *The Logic of Scientific Discovery* (*LScD*) is quite explicit. If T has been falsified, and a rival theory, T**, has not been falsified, has excess empirical content to T, and some of this excess content has been corroborated empirically, then T** is to be preferred to T. And this is the case even if T has not been ostensibly refuted. Popper's falsificationist philosophy of science is, on the face of it refuted. It declares that scientists should accept T**, and reject T, when scientists in fact, quite properly, do exactly the reverse. Accepting T** and rejecting T would be a disaster for science!

Popper does however have a reply. He can invoke simplicity. He can appeal to the methodological rule that that theory is to be preferred, other things being equal, that has the greater degree of simplicity. In terms of any intuitive notion of simplicity, it is clear that T is simpler than the grossly ad hoc rival T**.

But, for the Popper of *LScD*, this invocation of simplicity does not work. According to *LScD*, the simplicity of a theory is to be equated with its empirical content, its degree of falsifiability.[14] In terms of this Popperian notion of simplicity, T** is simpler than T because it has greater empirical content.

Thus, invoking simplicity in this way fails to save Popper from refutation. And, to make matters worse, Popper's notion of simplicity is clearly unacceptable. Popper's notion declares T** to be simpler than T, whereas of course in terms of any sensible notion, it is entirely the other way round. Not only has Popper's falsificationist methodology, as spelled out in *LScD*, been shown to be decisively refuted; his notion of simplicity has been shown to be hopelessly inadequate as well.

Popper did try to defend his falsificationist view against this decisive refutation of it. In his *Realism and the Aim of Science*, published in 1983, decades after *LScD*, he discussed "silly" rivals to accepted theories – grossly ad hoc rivals of the kind indicated above – and remarked: "Thus the belief that the duty of the methodologist is to account for the silliness of silly theories which fit the facts, and to give reasons for their *a priori* exclusion, is naïve: we should leave it to the scientists to struggle for their theories' (and their own) recognition and survival".[15] But this ignores that the "silly" rivals in question satisfy Popper's own methodological rules, as spelled out in Popper's *LScD*, better than the accepted theories: these rivals are, as I have said, unfalsified and more falsifiable; they have excess empirical content which has been corroborated. Popper's falsificationist methodology declares that these "silly" rivals, {T**}, are more acceptable than T – and yet in scientific practice they would never be considered for a moment, and it would be a disaster for scientific progress if they were. One can scarcely imagine a more decisive refutation of falsificationism than that. One might think that this refutation is not too serious, just because these "silly" theories really are very silly, not such as to be taken seriously at all. But actually the situation is all the other way round. The sillier these silly theories are, the more severe is the refutation. If falsificationism failed to discriminate between a number of reasonably good rival theories even though physicists in practice hold one to be the best, this might well be regarded as not too serious a failing. But falsificationism fails in a much more serious way than that; it actually favours and recommends a range of theories that are blatantly unacceptable, grotesquely "silly", thus revealing a quite dreadful inadequacy in the view. To argue, as Popper does, that these silly theories, refuting instances of his methodology, do not matter and can be discounted, is all too close to a scientist arguing that evidence that refutes his theory, should be discounted, something which Popper would resoundingly condemn. The falsificationist stricture that scientists should not discount falsifying instances (especially systematic falsifying instances), ought to apply to methodologists as well! Popper's attempt to discount this decisive refutation of his view is not commendable.[16]

5 Refutation of Popper's Philosophy of Science

As it happens, there is an argument that Popper could have deployed to justify the rejection of the infinitely many empirically more successful, ad hoc rival theories, {T**}, to the accepted theory, T. In his *Conjectures and Refutations* Popper put forward a methodological principle wholly in addition to those to be found in *LScD*. Popper declares:

> [A] new theory should proceed from some *simple, new, and powerful, unifying idea* about some connection or relation (such as gravitational attraction) between hitherto unconnected things (such as planets and apples) or facts (such as inertial and gravitation mass) or new 'theoretical entities' (such as field and particles). This *requirement of simplicity* is a bit vague, and it seems difficult to formulate it very clearly. It seems to be intimately connected with the idea that our theories should describe the structural properties of the world – an idea which it is hard to think out fully without getting involved in an infinite regress (Popper, 1963, p. 241).

Popper here gives a good intuitive idea as to what it is for a physical theory to satisfy this *requirement of simplicity*, but he fails to say precisely what it is for a theory to be simple or unified. A major problem arises because one and the same theory can be formulated in many different ways, some formulations yielding a beautifully simple and unified theory, other formulations yielding a horribly complex and disunified theory. And there are a number of other problems associated with the whole notion of the simplicity or unity of a theory, as I have shown elsewhere.[17] Many attempts have been made to solve the problem.[18] Even Einstein recognized the problem, and acknowledged that he did not know how to solve it.[19]

Let us grant, for the moment, that there is a significant notion of theory simplicity or unity sufficiently substantial to render all the infinitely many ad hoc rival theories {T**} unacceptably less simple than T. In this case, if we add Popper's new methodological rule, his *requirement of simplicity*, to the methodological rules of *LScD*, we do have grounds for rejecting highly corroborated, ad hoc rival theories to T. These theories may be more falsifiable, have greater empirical content, and be better corroborated, than T, according to *LScD*; however, they fail to satisfy the *requirement of simplicity*, and thus deserve to be rejected.

So far, so good. But there is a snag. If science adopts Popper's *requirement of simplicity*, that would mean that all those theories that fail to satisfy this requirement are to be rejected *even though there will be endlessly many such theories which will be better corroborated empirically than the theory that is accepted!* Persistent rejection of rival theories of this ad hoc type, better corroborated than the theory that is accepted, and thus against the evidence, amounts to just assuming: all such ad hoc theories are false. It amounts to adopting, implicitly, the metaphysical thesis of uniformity: the world is such that all ad hoc theories, however well corroborated or empirically successful they may be, are false.

This metaphysical assumption of non-ad hocness, this thesis of uniformity, must be held to be an item of scientific knowledge, whether this is explicitly acknowledged or not. For, any (ad hoc) theory that clashes with it, is to be rejected, however well-corroborated it may be.

Thus, as a result of adding the *requirement of simplicity* to the methodological principles of *LScD*, physics, pursued in accordance with these methodological principles, thereby unavoidably adopts the thesis of uniformity as an item of scientific knowledge, whether this is acknowledged or not.

But Popper cannot accept this consequence, for to do so is to acknowledge that a *metaphysical* thesis – the thesis of uniformity – is an item of scientific knowledge. That would be in flat contradiction with Popper's demarcation criterion. That means Popper cannot adopt his *requirement of simplicity* as a methodological principle of science. And that means it cannot be appealed to in order to reject empirically more successful, ad hoc, "silly" theories, {T**}, all rivals of the accepted theory T. Bereft of the *requirement of simplicity*, Popper's falsificationist methodology stands refuted. It recommends that any one of {T**} is to be preferred to T, which is exactly the wrong recommendation to make. Popper's entire philosophy of science has been found to be untenable. It is untenable with the *requirement of simplicity*; and it is untenable without it.

This refutation of Popper's philosophy of science is decisive. *Any* requirement of simplicity, not just Popper's, that is sufficiently robust to exclude empirically successful ad hoc theories from science, will carry the implication that science accepts, explicitly or implicitly, a metaphysical thesis of uniformity as an item of (conjectural) scientific knowledge. That clashes with Popper's demarcation criterion. On the other hand, if no such requirement of simplicity is adopted, Popper's falsificationist methodology is obliged to recommend acceptance of "silly", ad hoc rival theories, and the rejection of sensible, unified theories that are, in fact, accepted. Not only is Popper's methodology in stark contrast to scientific practice; it would be a disaster for science if it followed Popper's methodology, and began to accept "silly", ad hoc theories.

In one way, Popper's philosophy of science is revolutionary. It declares that there is no such thing as verified scientific knowledge at the level of laws and theories. But in another way, his philosophy of science is deeply traditional and conservative. It is a version of a view that may be called *standard empiricism*. This holds that the basic intellectual aim of science is truth, nothing being presupposed about the truth, the basic method being to assess theories with respect to evidence. Considerations of simplicity and unity may influence acceptance of theory as well, but not in such a way that the world itself is presumed to be simple or unified. A basic tenet of standard empiricism is that *science must not accept any thesis about the world as a part of scientific knowledge independent of evidence, let alone in violation of evidence*.

Standard empiricism, as just characterized, is widely, and almost unthinkingly taken for granted by scientists and philosophers of science.[20] And it is accepted by Popper too. But it is untenable, as we have just seen. In order to make it work, physics must persistently accept *unified* theories and persistently reject infinitely many disunified rivals that fit available data better than the theory that is accepted. In doing that, physics accepts, implicitly or explicitly, a metaphysical thesis of uniformity, and that contradicts standard empiricism. This simple argument suffices to refute Popper's falsificationism, but it suffices to refute inductivist and verificationist rivals too, such as "inference to the best explanation" and Bayesianism.[21]

6 Improving Popper

The decisive refutation of Popper's philosophy of science, just outlined, can however easily be overcome. All that needs to be done is to make the following six important improvements to Popper's view.

(1) Add explication of what theory unity means (and reject Popper's LScD account of theory simplicity). Adopt corresponding methodological principle.
(2) Acknowledge that persistent acceptance of unified theories only, implies that a metaphysical thesis of uniformity is an item of scientific knowledge
(3) Accept requirement of intellectual rigour, and its implications for science
(4) Reject Popper's demarcation criterion
(5) Adopt methods which best facilitate the improvement of metaphysical presuppositions of science.
(6) Add the solution to the problem of verisimilitude

I now take these six points in turn. Note that, in what follows, I take Popper's falsificationist philosophy of science as the starting point, and I modify this view, step by step, by adding to it, or modifying it, in the ways indicated in the above six points.

(1) Add explication of what theory unity means (and reject Popper's *LScD* account of theory simplicity). In order to explicate what it means to assert of a physical theory that it is unified or disunified to degree N, we need to attend to the following points. First, we need to restrict our attention, initially at least, to fundamental physical theories. Secondly, we need to attend, not to the theory itself, its structure or formulation, but to the universe, or rather to what the theory asserts about the universe, the *content* of the theory in other words. Third, we need to concentrate on what it means to assert, not that a theory, T, is unified, but rather on what it means to assert it is disunified, to degree N. Fourth, the account of theory unity that emerges, in order to be acceptable, must be such that it declares unequivocally that all the ad hoc, "silly" theories considered in section 4 above, are disunified.

Here, in outline, is the solution to the problem. A physical theory, T, is disunified to degree N if what it asserts about all possible phenomena to which it applies divides into N domains such that what T asserts in any one domain is the same everywhere in that domain, but differs from what T asserts in all the other domains.[22] T is unified if N = 1.

In terms of this notion of theory unity, we may declare Newtonian theory to be unified, with N = 1, in that the two basic laws of Newtonian theory – what is asserted by the theory about phenomena – remain the same as we move around in space and time, and as we vary the value of other variables, such as mass, temperature, or substance, This is not the case as far as the ad hoc variants of Newtonian theory are concerned. What these theories assert changes dramatically, as we vary the value of some variable. These theories are disunified to degree N = 2. And it is easy to imagine even more ad hoc variants of Newton, with N = 3, N = 4, and so on.[23]

This proposal as to what we should mean by theory unity is clearly a great improvement over Popper's requirement of simplicity. It is also an improvement over other proposals that have been put forward.[24]

We can now specify, in general terms, the improved methodology to replace what Popper proposes in *LScD*. A new physical theory, T, in order to be acceptable, must be (1) sufficiently empirically successful, and (2) sufficiently unified in the sense just indicated.

(2) Acknowledge that persistent acceptance of unified theories only, implies that a metaphysical thesis of uniformity is an item of scientific knowledge. As I have already argued, physics, in persistently only accepting unified theories, all empirically more successful disunified rivals being ignored, thereby makes a persistent assumption about the nature of the universe: it is such that all disunified theories are false, whatever their empirical success may be. Some kind of metaphysical thesis of uniformity is thereby assumed to be true.

If physicists only ever accepted theories that postulate atoms, and ignored all theories that postulate fields, even though they are much more successful empirically, it would be quite clear: these physicists are just assuming that the universe is composed of atoms; they are just assuming that the universe is not made up of fields. Precisely the same considerations arise in connection with unity and disunity.

Inductivists and confirmationists may object that the disunified rivals are not "more successful empirically". Disunified theories are inherently less verifiable than unified ones. But whether this is the case or not depends on what kind of universe we are in. In a world that is such that the uniformity thesis is true, unified theories will of course tend to fare better empirically than disunified ones. But in a universe which is such that it has some characteristic kind of disunity built into it, it will be the correspondingly disunified theories that will meet with empirical success, not invariably the unified theories. Any decision as to what kind of theory is inherently the most verifiable amounts to a decision as to what kind of universe we are in; it does not obviate that decision.

Popper, and Popperians, cannot however employ this counter-argument. They hold that no theory is verifiable empirically, to any degree of probability greater than zero.

(3) Accept requirement of intellectual rigour, and its implications for science. A basic requirement for intellectual rigour is that assumptions that are substantial, problematic, influential, and implicit, need to be made explicit, so that they can be critically assessed, so that alternatives can be developed and assessed, in the hope that an improved assumption will be discovered and adopted. The metaphysical thesis of uniformity is substantial. It is highly problematic, if only because it is a pure conjecture about the nature of the universe. It exercises a massive influence over physics, and thus over the whole of natural science, in influencing both what theories physicists try to discover, and what theories they accept. And, as we have seen, its acceptance is implicit in the persistent acceptance of unified theories, and the persistent rejection of infinitely many empirically more successful disunified rivals. Thus, if physics is to meet elementary standards of intellectual rigour, it must acknowledge this implicit assumption of uniformity explicitly, so that it can be critically assessed and improved as an integral part of physics itself.

There is enormous resistance to acknowledging the force of this argument, both among Popperians and other philosophers of science, and among scientists themselves.[25] Popper would object to it, on the grounds that it involves acknowledging that a metaphysical conjecture is an item of scientific knowledge. Nevertheless, the argument is valid. Persistent acceptance of unified theories, and persistent rejection of infinitely many empirically more successful (better corroborated) disunified rivals does imply that a substantial thesis about the nature of the universe is accepted, whether implicitly or explicitly: physics is more rigorous intellectually if this at present implicit metaphysical thesis is made explicit, so that it can be critically assessed and, we may hope, improved.

This is a highly Popperian argument. Popper's philosophy is all about the value of criticism for provoking progress. It should be clear to everyone that physics becomes more rigorous intellectually if its implicit metaphysical presuppositions are acknowledged explicitly, and thus thrown open to critical appraisal; this should be especially clear and obvious to followers of Popper. Popper's philosophy of science is radically improved by the addition of points (1), (2) and (3).

(4) Reject Popper's demarcation criterion. This becomes obligatory once point (2) is accepted. Physics accepts, as an item of scientific knowledge, the metaphysical thesis of uniformity: that refutes Popper's demarcation criterion between science and non-science.

(5) Adopt methods which best facilitate the improvement of metaphysical presuppositions of science. Intellectual honesty compels us to acknowledge that persistent acceptance of unified theories, and persistent rejection of infinitely many empirically more successful, disunified rival theories, has the implication that physics accepts a metaphysical thesis of uniformity, as an item of conjectural scientific knowledge. But, as I have repeatedly stressed, this thesis of uniformity is profoundly problematic. That is the reason why, indeed, it needs to be made explicit within physics. The thesis of uniformity is problematic, first because it is not entirely clear what it is that it asserts,[26] and second because it is a pure conjecture about the ultimate nature of the universe, all too likely to be false.

Since physics cannot proceed without accepting some version of this metaphysical thesis of uniformity, whether honestly acknowledged or dishonestly disavowed, the crucial question that needs to be answered is simply this: How can we best set about improving this thesis of uniformity? What methodology gives us our best chance of improving the thesis – clarifying what it asserts, and rendering it more likely to be true, and more fruitful for theoretical physics? Elsewhere I have shown in some detail that the answer to this question is a methodological view I call *aim-oriented empiricism* (AOE).[27] Here I will be brief.

In order to subject the problematic thesis of uniformity to the kind of scrutiny that is required, to give us our best chance of improving it, we need to represent it in the form of a hierarchy of theses, these theses asserting less and less as we go up the hierarchy, and thus becoming more and more likely to be true, and also becoming more nearly such that their truth is required for science to be possible at all: see Figure. As we descend the hierarchy of theses, they become increasingly substantial, and thus increasingly likely to be false. Criticism and attempted improvement need to be concentrated low down in the hierarchy, at levels 3 and 4 in the Figure.

At level 7 in the Figure we have the thesis that the universe is such that we can acquire knowledge of our local circumstances sufficient to make life possible. If this thesis is false, we have had it, whatever we assume. Even though we have no good reason to hold this level 7 thesis is true, it can never hinder the pursuit of knowledge to accept the thesis as a part of our knowledge, and may well help this pursuit. At level 6 there is the more substantial thesis that the universe is such that we can make a discovery about it which enables us to improve our methods for the improvement of knowledge. The universe is such, in other words, that we can *learn* how to learn. At level 5 there is the even more substantial thesis that the universe is comprehensible in some way. There is a standard kind of explanation as to why phenomena occur as the do. It might be that they occur as a result of the will of God, or to fulfil a cosmic purpose, or to be in accordance with something like a computer programme, or to accord with a unified pattern of physical law. This conjecture exemplifies the level 6 thesis since it holds out the promise that, by modifying our ideas about how the universe is comprehensible to accord with those explanatory theories that meet with the most empirical success, we will be able progressively to improve our methods for discovering and accepting new theories. The level 4 thesis of physicalism has arisen in precisely this way. It asserts that the universe is such that all phenomena occur in accordance with a unified pattern of physical law. This thesis has proved to be astonishingly fruitful empirically, in that the whole enterprise of theoretical physics accords with it. Ever since Galileo, as physics has progressed, the totality of fundamental physical theory has become both (1) increasingly unified, and (2) increasingly vast in empirical scope, in that more and more phenomena are successfully predicted with increasing accuracy. At level 3 there is our best conjecture as to what specific kind of unified pattern of physical law is inherent in all phenomena. Here, we are almost bound to get things wrong, as the historical record indicates.

Associated with each metaphysical thesis, at levels 7 to 3, there are methods which require that theses and theories, lower down in the hierarchy, must be (as far as possible) compatible with the given thesis. At level 3, that thesis is to be accepted which best accords with the thesis at level 4 and, at the same time, accords best with the most empirically successful physical theories, at level 2. The hope is that, as a result of modifying the thesis at level 3 so that it accords better with the level 4 thesis, ideas for good new level 2 theories will emerge, new metaphysics leading to new physics. As physics advances, and theoretical knowledge at levels 1 and 2 improve, so too metaphysical conjectures at levels 3 and 4 may improve as well, this leading to an improvement in associated *methods*. Something like positive feedback can take place between improving knowledge and improving theses and associated methods – improving knowledge about how to improve knowledge, in other words.

This process of positive feedback between improving knowledge, and improving methods for the improvement of knowledge, has actually gone on in science,[28] but in a somewhat furtive, curtailed fashion, due to the general acceptance of standard empiricism and the failure of the scientific community to conceive of and adopt AOE – the hierarchical conception of scientific method depicted in the Figure.[29] The extraordinary success of physics is due to the somewhat constrained implementation of

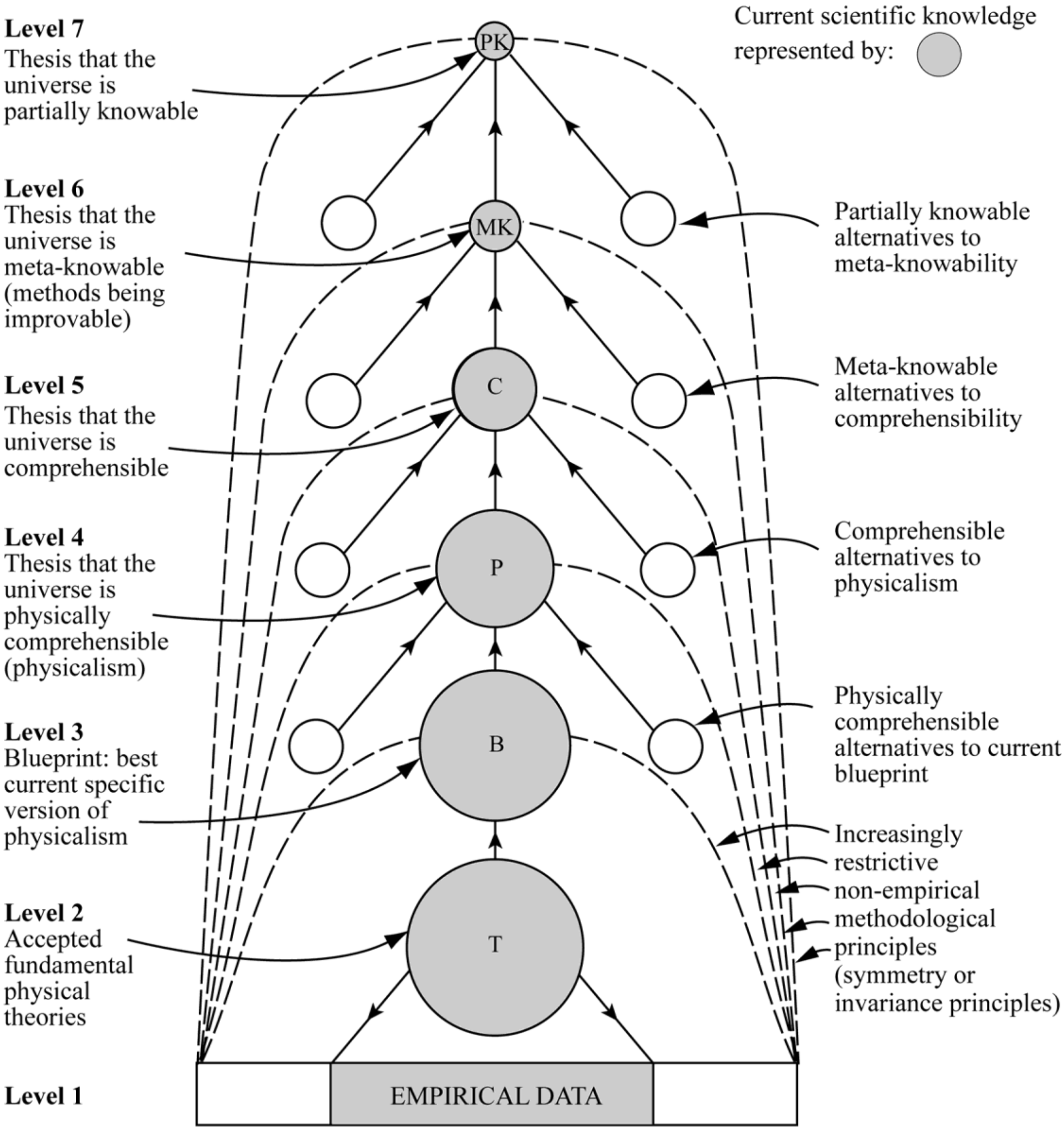

Figure: Aim-Oriented Empiricism (AOE)

aim-oriented empiricism (AOE) – constrained as a result of the (mistaken) conviction of the physics community that they ought to implement standard empiricism.[30]

What I have said so far about problematic *theses and methods* can be reformulated to be about problematic *aims and methods*. The basic aim of physics is not truth *per se*, as standard empiricism assumes. It is rather truth *presupposed to be unified* or *explanatory*. Precisely because this aim is so profoundly problematic (we conjecture that the truth is explanatory, but do not know), we need to represent this problematic aim in the form of a hierarchy of aims – aims becoming increasingly unproblematic as we ascend the hierarchy, and metaphysical assumptions implicit in the aims become increasingly lacking in specific, substantial content. In this way, we provide ourselves with a fixed framework of relatively unproblematic aims and associated methods (high up in the hierarchy), within which much more problematic aims and associated methods may be improved, in the light of which meet with empirical success and which do not, as we proceed with scientific research. Aims and methods evolve with evolving scientific knowledge.

This is the conception of scientific method, implicit in scientific practice since Galileo and Newton, that is responsible for the astonishing progress achieved by natural science over the centuries.[31]

There is, however, a well-known and apparently devastating objection to AOE – to the claim, in particular, that AOE solves the problem of induction. According to AOE, those metaphysical theses (low down in the hierarchy of theses) are accepted which best accord with accepted physical theories; at the same time, those physical theories are accepted which best accord with the metaphysical theses. Acceptance of empirically successful physical theories is justified by an appeal to metaphysical theses; acceptance of these metaphysical theses is then justified by an appeal to the astonishing success of physics! But such an argument is, it seems, viciously circular. It presupposes just that which it sets out to justify. How can AOE survive this devastating criticism of vicious circularity?

The solution to this problem stems from the level 6 metaphysical thesis of meta-knowability. Permitting metaphysical assumptions to influence what theories are accepted, and at the same time permitting the empirical success of theories to influence what metaphysical assumptions are accepted, may (if carried out properly), in certain sorts of universe, lead to genuine progress in knowledge. Meta-knowability is to be interpreted as asserting that this is just such a universe. And furthermore, crucially, reasons for accepting meta-knowability make no appeal whatsoever to the success of science. In this way, meta-knowability legitimises the potentially invalid circularity of AOE.[32]

Popper's philosophy of science, modified in the five ways I have indicated so that it becomes AOE, provides us with a radically improved conception of science. Whereas Popper's falsificationism stands refuted, as are all versions of standard empiricism, as we have seen, AOE is not refuted. Whereas falsificationism, and all versions of standard empiricism, fail to solve the problem of induction, and thus fail to represent science as a rational enterprise, AOE succeeds in solving the problem.[33] In addition, AOE has the great advantage over all versions of standard empiricism, including falsificationism, that it is able to fine tune, to improve, non-empirical requirements a theory must satisfy to be acceptable, as physics proceeds. In order to be acceptable a physical theory must accord, as far as possible, with the accepted level 3 thesis; but that thesis is improved, as physics proceeds, to accord better with the level 4 thesis, and empirically successful theories at level 2. A further, related advantage of AOE is that it provides physics with a rational, if fallible, method of discovery,[34] something no standard empiricist conception of science can do. And there are a number of additional advantages to AOE.[35]

One final addition to Popper's philosophy of science is required, namely:-

(7) Add the solution to the problem of verisimilitude. The problem of verisimilitude is the problem of what it can mean to say of two false theories that one is closer to the truth than the other. This problem becomes important once it is appreciated that, as far as theoretical physics is concerned at least, science advances from one false theory to another. Simply in order to say what it *means* to declare that science makes progress in such contexts, the problem of verisimilitude must be solved. It is to Popper's great credit that he discovered the problem – but his attempted solution failed.[36] It is not quite correct to say that AOE solves the problem, but the line of thought introduced by AOE does solve the problem, in that the solution requires one to appeal to the true physical "theory of everything",[37] the precise, testable version of the level 4 thesis of physicalism (something Popper would never have appealed to). Given two false physical theories, T_1 and T_2, T_1 is closer to the truth than T_2 if the true physical "theory of everything", T, approximately implies T_1, T_1 approximately implies T_2, but T_2 does not approximately imply T_1.

What does it mean for T_1 to "approximately imply" T_2? This notion is best clarified by way of an example. Let us consider the manner in which Newtonian theory may be said to "approximately imply" Kepler's laws of planetary motion. This is done in three steps. First, Newtonian theory is restricted to any N body system, confined to a specific region of space, the bodies interacting by means of Newtonian gravitation, one body much more massive than all the others put together. Second, while the mass of the massive body, dubbed the sun, is kept constant, the masses of all the other bodies, dubbed planets, tend to zero, the spatial paths being specified in the limit of zero mass. In the limit of zero mass, the paths of the planets conform to Kepler's laws. Third, the resulting theory is reinterpreted to be about a system with the planets having non-zero mass, but in sum much less than that of the sun. The outcome is Kepler's laws applied to a system of bodies such as that of the solar system. Thus Newtonian theory "approximately implies" Kepler's laws means that Kepler's laws are arrived at by means of the three steps indicated: first, restriction of the scope of Newtonian theory; second, limits taken, in that finite quantities (mass) tend to zero; and third, the resulting theory is reinterpreted to be about systems before limits were taken (before mass became zero). It is of course the third step that introduces error, and ensures that Kepler's laws, in their original form, are incompatible with Newtonian theory (because the planets attract each other, and attract the sun, a solar system obeying Newton's laws thus deviating from Kepler's laws).

More generally, to say that physical theory T_1 "approximately implies" T_2 is to say that a theory empirically equivalent to T_2 can be extracted from T_1 by means of some finite sequence of steps on the kind just indicated: restriction of scope; values of constants or variables set to zero; the resulting theory reinterpreted to be about physical systems with original values of constants and variables restored.

It might be thought that this notion of "approximate derivation" is problematic, despite what has been said in support of it. But it needs to be appreciated that approximate derivations are ubiquitous in physics. All too often, when laws or experimental results are derived from theory, higher terms in an expansion of terms are set to zero, limits are taken, approximations made. And in any case, a sound but formally invalid approximate derivation could always be replaced by a strictly valid derivation, that issues in a result that "approximates" sufficiently closely to the result of the "approximate derivation".

A second method is available for explicating what it means to say, of two false physical theories, that one is closer to the truth than the other, based this time on a comparison of the accuracy and scope of approximate true predictions the two theories make about the evolution in time of the state of any isolated system to which one or both theories apply. Suppose T_1 applies to all physical systems that T_2 applies to, and possibly also applies to systems that T_2 does not apply to. Suppose T_1 and T_2 both predict how an isolated system evolves in time, but the most precise, approximate, true prediction of T_1 is more precise than the similar most precise, approximate true prediction of T_2, so that what T_1 predicts correctly implies what T_2 predicts correctly, for all isolates systems to which both theories apply, and for all predictions of this type.[38] Then we may declare that T_1 is more accurate than T_2. If, on the other hand, T_1 is at least as accurate as T_2, but there are physical systems to which T_1 applies and makes approximate true predictions about, but to which T_2 does not apply, then we may say T_1 is more extensive than T_2. If T_1 is more accurate than T_2, or more extensive, or both, then T_1 may be said to be closer to the truth than T_2.

We have before us two methods for explicating what it means to say of two false theories that one is closer to the truth than the other. The first method interprets "T_1 is closer to the truth than T_2" to mean, roughly, that the theoretical structure, the content, to T_1 is closer to the truth – to the true "theory of everything" – than T_2. The second method interprets the assertion to mean, roughly, that T_1 has greater true predictive content about phenomena than T_2. We may now hold that, for T_1 to be closer to the truth than T_2 in the full sense, it needs to be the case as far as *both* methods are concerned.[39]

Accept standard empiricism, accept that physics advances from one false theory to another, and the prospects for real scientific progress in theoretical knowledge look rather bleak. It has even led one standard empiricist philosopher of science to put forward "the pessimistic induction":[40] the fact that most theories proposed so far, despite initial success, have turned out subsequently to be false should lead us to conclude that all theories in the future will similarly turn out to be false. That standard empiricism has not as yet come up with a solution to the problem of verisimilitude makes the situation even worse. One cannot even say, it seems, what it would *mean* for a sequence of false theories to be getting closer and closer to the truth – let alone justify that this is what science is in fact achieving.

But this bleak assessment of the prospects for scientific progress change dramatically once AOE is accepted, and the solution to the problem of verisimilitude just indicated is adopted as well. The crucial point to appreciate is that, if the level 4 thesis of physicalism is true, then physics – in advancing from one false theory to another in the way that it has done since Kepler and Galileo – is precisely the way physics should advance if it is in reality making terrific progress towards discovering the truth – the ultimate nature of the physical universe. For, granted the truth of physicalism, that which determines precisely the way any specific kind of phenomenon evolves in time is exactly the same as that which determines precisely the way any other kind of phenomenon evolves. That is just what physicalism asserts: what determines precisely the way phenomena evolve is the same for all physically possible phenomena everywhere. Thus, any theory that specifies precisely how any specific kind of phenomenon evolves must, if true, be instantly generalizable so as to specify precisely how all physically possible phenomena evolve. On the other hand, a theory that cannot be instantly generalized to apply correctly to all phenomena cannot be precisely correct about the phenomena to which it does apply. It must, in short, be false. Thus, given that physics advances by developing theories of limited, but ever increasing scope, and ever increasing theoretical *unity*, all these theories must turn out to be false *if physics really is making splendid progress towards capturing the truth in a true, unified theory of everything*. That these successive theories all turn out to be false, far from indicating no progress, do exactly the opposite: these successive theories *must* all turn out to be false, if physics really is making progress towards capturing the truth in a true, unified "theory of everything". The so-called "pessimistic induction", viewed from the standpoint of AOE, is a fantastic indication that real scientific progress is being achieved.

Galileo's laws of terrestrial motion and Kepler's laws of planetary motion are revealed to be false by Newtonian theory; Newtonian theory, in turn, is revealed to be false by special relativity; special relativity is shown to be false by general relativity; general relativity is shown to be false by quantum theory; quantum theory reveals that the whole of classical physics is false; quantum theory is revealed to be false by QED; that theory, in turn, is revealed to be false by quantum electroweak theory. All this may be construed to indicate that scientific progress is in doubt, when viewed from the standpoint of standard empiricism. But when viewed from the standpoint of AOE, the implication is exactly the opposite! This is just the way physics *must* advance, granted it really is making progress towards capturing the true "theory of everything". Especially is this the case in view of the fact that the successive theories indicated all satisfy the requirement for being (false) theories that are getting closer and closer to the truth: theories of ever-increasing unity, and ever-increasing accuracy and scope.

That physics advances in this way, from one false theory to another, but to theories of ever greater unity, accuracy and scope, does not of course *prove* that physics is making progress. Such advance is not *sufficient* for progress. But it is *necessary*. Physics must advance in this way *if* it is to be making real progress. Far from indicating no progress, it indicates just the opposite: it is a good indication that real progress is in fact being made.

7 A Perfect Simulacrum of Verification

Let us now suppose that AOE is correct and true, to the extent at least that it depicts the proper, correct methods of natural science, and the theses from level 7 to 4 are true. At once we have an explanation as to why fundamental theories of physics, selected in the way that they are, though all false so far, nevertheless take us progressively closer and closer to the truth.

A new fundamental theory of physics, in order to be accepted, must satisfy two basic requirements. (1) Its true approximate predictions must be more accurate, and more extensive, than predecessor theories; phenomena that refute predecessor theories must not refute the new theory. (2) When added to the totality of fundamental physical theory, T, replacing predecessor theories, or relevant empirical laws if there is no predecessor theory, the outcome must be the enhanced unity of T.[41]

It may be objected that this does not take into account a basic requirement a physical theory must satisfy to be acceptable; it must exhibit a symmetry principle. But elsewhere I have shown that symmetry is an aspect of unity. In demanding that a theory accords with Lorentz invariance, global or local gauge invariance, or supersymmetry – all relevant to contemporary physics – we demand that the theory in question meets a requirement for theoretical *unity*.[42]

The crucial point to appreciate is now this. Let T_1, T_2 ... T_n be successive totalities of fundamental physical theory (or empirical laws if there is no theory), generated by the pursuit of physics for, perhaps, many decades, or even a century or two. Granted the truth of the level 4 thesis of physicalism, *if* T_1, T_2 ... T_n, in turn, satisfy both (1) and (2), we have every reason to hold that this succession of theories is getting closer and closer to the truth in the full sense explicated above. For (1) and (2) are precisely the requirements that need to be satisfied by a succession of theories, if that succession is to be getting closer and closer to the truth (as we saw above). If physicalism is false, then the apparent astonishing progressive success of T_1, T_2 ... T_n may well be an illusion. Tomorrow, the laws of nature may abruptly and inexplicably change, and all our incredibly successful physics may turn out to be a pure illusion. The *mere* fact that the succession T_1, T_2 ... T_n satisfies, in turn, both (1) and (2), does not, in itself, establish that this succession of physical theory really is getting progressively closer and closer to the truth. But if physicalism is *true*, it is very hard to see how T_1, T_2 ... T_n could, in turn, satisfy both (1) and (2), and *not* be getting closer and closer to the truth.

What this result establishes is that AOE, if correct and true to the extent indicated, provides a perfect simulacrum of verification of theory by evidence. The successive totalities of fundamental physical theory, T_1, T_2 ... T_n, are not verified empirically, of course, because they are all false. In each case, truth lies in the standard approximate empirical *predictions* of these theories. If the level 4 thesis of physicalism can be taken to be *true*, and T_1, T_2 ... T_n in turn satisfy (1) and (2), then we have every reason to suppose that the standard approximate empirical predictions of T_1, T_2 ... T_n will be true, the true empirical predictions of these theories becoming progressively more and more accurate and more and more extensive. We have only a *simulacrum* of verification because it is obligatory to take physicalism to be *true*, whereas in reality it is a *conjecture* which, at most, may be true. Nevertheless, *if* physicalism is true, we can understand why it is that physical theories, selected on the basis of satisfying requirements (1) and (2), should meet with ever-increasing empirical success, successive theories receiving apparent verification to the extent that their standard approximate empirical predictions continue to be verified, and are increasingly accurate and extensive as physics advances.

It is, furthermore, quite clear why grossly ad hoc theories even more successful empirically than a theory that is accepted – such as the grossly ad hoc versions of Newtonian theory considered in section 4 – need to be rejected. They all clash with the level 4 thesis of physicalism. It is the implicit presupposition of physicalism in physics which makes it possible for there to be a simulacrum of verification of theory by evidence in physics.

AOE may, in this way, provide a qualified simulacrum of verification for theoretical physics, but what, it may be asked, about the rest of natural science? It is vital to appreciate that the various branches of natural science are not isolated from one another, but form an interconnected whole. The more empirical branches of physics presuppose fundamental theoretical physics, chemistry presupposes relevant aspects of physics, as does astronomy, cosmology, geology, molecular biology, and other branches of natural science. And biology as a whole presupposes relevant parts of physics, chemistry, geology and even astronomy.

If laws and theories proposed in any part of natural science other than fundamental theoretical physics were accepted solely on the basis of evidence, it would be very hard to understand how they could ever be accepted as contributions to knowledge, since endlessly many ad hoc rival theories would always be available, just as successful empirically, if not more so (as we have seen in effect above). But it never happens that proposed theories are accepted *solely* on the basis of evidence. Such potential contributions must always satisfy *two* requirements to be accepted. They must be (1) sufficiently empirically successful, and (2) they must accord with the accepted results of relevant more fundamental sciences. Just as acceptance of fundamental physical theory is constrained by (1) evidence, and (2) compatibility, as far as possible, with accepted metaphysics, so too acceptance of a potential contribution to chemistry, let us say, is constrained by (1) evidence, and (2) compatibility, as far as possible, with relevant accepted physics. It is requirement (2) that excludes empirically successful, ad hoc theories from consideration, and creates the illusion that contributions to chemistry are regularly *verified by evidence*. And it is in this way, more generally, throughout natural science, that the illusion of verification by evidence is created, and we have the perfect simulacrum of verification. To that one might add that the metaphysical thesis of uniformity also exercises a surreptitious, unacknowledged influence, not just in physics, but throughout natural science. That helps create the illusion that contributions to natural science are regularly verified by evidence (the persistent ignoring of empirically more successful ad hoc rivals constituting implicit acceptance of the metaphysical thesis of uniformity).

One implication of the whole argument of this paper is that science would be more honest, more intellectually rigorous and, potentially, more successful if it acknowledged problematic metaphysical conjectures implicit in persistent rejection of empirically more successful, ad hoc rival theories. And indeed, our whole science and technology based society and culture would be more intellectually honest if this point were acknowledged. Elsewhere I have shown that the progress-achieving methods of AOE, when generalized, have revolutionary implications for social science, for academic inquiry as a whole, and for our capacity to tackle the grave global problems, such as the climate crisis, that threaten our future.[43] There are powerful scientific, intellectual, humanitarian and moral grounds for improving Popper's philosophy of science in the way that I have indicated, accepting AOE, and putting it into scientific practice.

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Notes

[1] What do I mean by "verification"? I mean this. A theory verified by evidence is one sufficiently well supported by evidence to justify confidence that its standard empirical predictions, to standard degrees of accuracy, are true, this confidence being such that we are prepared to entrust our life to the correctness of these predictions. ("p" is true iff p.) This way of construing "empirical verification" allows us to speak of verifying a physical theory even though we acknowledge that almost all precise physical theories are false. However, even in terms of this somewhat modest notion of verification, in the essay I argue that there is no such thing as the verification of theory by evidence. There is, at most, a *simulacrum* of verification of theory by evidence, not verification by evidence as such. If we were justified in holding that the metaphysical thesis of physicalism is true, then there would, on occasions, in appropriate circumstances, be authentic verification of a theory – one that is sufficiently empirically successful, and sufficiently in accord with physicalism. I shall argue that we have valid grounds for accepting physicalism as a part of scientific knowledge, but that does not extend to being justified in holding that physicalism is true. Physicalism is to be understood, here, as the thesis that he universe is such that all phenomena occur in accordance with a unified pattern of physical law. (What "unified" means in this context will be clarified as we proceed.)

[2] See, however, Maxwell (2017a, especially ch. 9).

[3] Maxwell (1972); Stove (1982); Worrall (1989).

[4] Maxwell (1974; 1993, pp. pp. 61-79; 1998; 2019a).

[5] What follows is a much improved formulation of Hume's problem of induction. I have formulated it in somewhat similar ways elsewhere: see Maxwell (2017a, pp. 24-9; 2017b, pp. 74-83). I repeat the argument here because (a) it is required for the argument of this paper, (b) it is of fundamental importance to the philosophy of science, and (c) it seems that it is not widely understood and appreciated by philosophers of science.

[6] These considerations concerning empirically successful ad hoc theories may seem reminiscent of Goodman's considerations concerning grue and bleen: see Goodman (1954). Actually, there is a substantial difference. For a critical discussion of Goodman, see Maxwell (1984, 2nd ed., pp. 385-6; 1998, pp.155-7; 2004, pp. 171-2; 2017a, pp. 47-8; or 2017c, pp.137-8).

[7] Discovering how to justify the rejection of these infinitely many empirically more successful ad hoc rival theories to any accepted physical theory is of course Hume's problem of induction. The problem, as formulated here, is an intensification of Hume's version of the problem. Hume considered the possibility that the laws of nature might abruptly change, but he did not consider the infinitely many different ad hoc theories that postulate such a change. He did not consider changes in the laws of nature that arise in connection with the variation of variables other than time – such as space, mass, temperature, and so on. And he did not consider the infinitely many ad hoc theories that are even more empirically successful than the physical theory that we accept.

[8] Whenever philosophers discuss the thesis of uniformity, they tend to mean uniformity of the laws of nature with respect to time, or time and space. Uniformity with respect to other variables, such as mass, charge or temperature, tend to be ignored. Uniformity with respect to time and space is, however, insufficient; we require uniformity with respect to other variables as well, if we are to do justice to what goes in in practice in physics.

[9] It may not be entirely clear as to what it is that this thesis of uniformity asserts, in the main because it may not be clear what it means to say of a theory that it is "ad hoc". This issue will be clarified below.

[10] Inductivists and confirmationists will object that any ad hoc theory that postulates an abrupt change in the laws of nature, however well it may fit available data, is to be rejected, not because it clashes with the uniformity thesis, but because it is inherently less verifiable than its non-ad hoc rival. This objection is rebutted below.

[11] Reichenbach (1961, pp. 6-7); Popper (1959, p. 31).

[12] Popper held on to his principle of demarcation, and stressed its significance, throughout his career: see for example Popper (1983, pp.159-174).

[13] Popper (1959, pp. 252-4).

[14] *LScD* specifies another conception of simplicity, based on what Popper calls the "dimension" of a theory: given two theories, T_1 and T_2, if the number of basic statements required to refute T_1 is greater than the number required to refute T_2, then T_2 is simpler than T_1. Popper is emphatic, however, that if these two requirements of simplicity clash, the one that holds that the theory with the greater empirical content is the simpler is to be preferred: Popper, (1959, chs. vi-vii). This accords with the basic theme of *LScD*: everything stems from falsifiability. We can, then, ignore Popper's notion of simplicity based on the idea of "dimension", and concentrate on the notion indicated in the text, based on the notion of the degree of falsifiability of a theory, or its empirical content.

[15] Popper (1983, p. 70).

[16] Popper might declare that his methodology cannot be refuted because it is about what scientists *ought* to do, not what they *in fact* do: he almost says this in Horgan (2018). But that ignores that here we have a case where we would all agree, Popper included, that scientists very definitely ought not to do what falsificationism says they ought to do. Falsificationism is refuted by what scientists in fact do, and what everyone would agree they *ought* to do.

[17] See Maxwell (1998, pp. 104-106).

[18] See Jeffreys and Wrinch (1921), Popper (1959, chs. vi-vii), Friedman (1974), Kitcher (1981; 1989), Watkins (1984, pp. 203-213), Bartelborth (2002), McAllister (1996), Weber (1999) and Schurz (1999). For criticisms of these proposals see Maxwell (1998, pp. 56-68; 2017c, ch. 4 and 6).

[19] See Einstein (1982, p. 23).

[20] See Maxwell (1998, pp. 38-44; 2004, p. 13n14; 2017a, p. 16-17; 2017b, pp. 73-4).

[21] For "inference to the best explanation" see Harman (1965); for Bayesianism, see Howson and Urbach (1993). Both views are versions of standard empiricism; the refutation of standard empiricism thus refutes both views.

[22] In any one domain, we retain that part of T required to predict the evolution of phenomena in that domain, and we discard any content of T that is not required. Any domain must include a range of phenomena, however small, to avoid the possibility that T acquires an especially simple form for an especially symmetric physical system.

[23] For further developments of this account of theory unity, including an account of the role that symmetry principles play in it, see Maxwell (2017a, ch. 5 and appendix 1).

[24] For references to rival proposals, and criticism of them, see note 18.

[25] I have tried, again and again, to break down the dogmatic view that science does not make any metaphysical assumption about the nature of the universe: see Maxwell (1974; 1993; 1998; 2004; 2011; 2017a-c; 2019). So far, I have failed to make a dent in this dogmatic conviction. It might be thought, perhaps, that Kuhn (1962) and Lakatos (1970) both reject the dogmatic doctrine. Not so; both hold that "paradigms" or "hard cores" are accepted and rejected, ultimately, on empirical grounds: see Maxwell (1998, p. 40).

[26] It might be interpreted, at one extreme of precision and content, to assert: the universe is such that any physical theory which shows any sign whatsoever of being slightly ad hoc, is false. In other words, it might be interpreted to assert: the universe is such that only a physical "theory of everything" that is perfectly unified is true. At the other extreme of imprecision and lack of content, it might be interpreted to assert: the universe is such that a physical theory that is ad hoc in space or time is false – but theories that are ad hoc in less extreme ways may well be true.

[27] For a recent, detailed exposition of AOE, see Maxwell (2017a); see also Maxwell (2017b; 2017c). For earlier expositions, see Maxwell (1974; 1993; 1998; 2004).

[28] It is a platitude that this goes on at the experimental level. New knowledge leads to the development of new methods – new instruments, for example, such as the telescope or particle collider – which in turn lead to new knowledge. Because of the pernicious influence of standard empiricism, it is less widely appreciated that it goes on at the theoretical level as well (just as AOE says it should). A classic case in point is the way Einstein's special theory of relativity becomes a methodological principle (an acceptable theory must be Lorentz invariant) which in turn contributes to the discovery and acceptance of major new physical theories, such as quantum electrodynamics and quantum chromodynamics.

[29] For much more detailed expositions of, and arguments for, AOE, that have been progressively improved over the years, see works referred to in notes 25 and 27.

[30] See Maxwell (1993, pp. 275-305) for an account of Einstein's exploitation of AOE in discovering special and general relativity. See Maxwell (2017b, ch. 5) for an account of how physics would have met with even greater success if it had implemented AOE explicitly over the centuries, undistracted by standard empiricism.

[31] For a discussion of this issue see especially Maxwell (2017b, especially chs. 1, 2, and 5).

[32] See Maxwell (2017a, ch. 9) for a more detailed exposition of this point.

[33] See Maxwell (2017a. especially ch. 9).

[34] See Maxwell (1993, pp. 275-305; 2017b, ch. 5).

[35] See Maxwell (2019, pp. 106-8).

[36] For Popper's proposed solution, see Popper (1963, pp. 231-7). For decisive criticisms, see Tichý (1974), Miller (1974).

[37] A physical "theory of everything" is a fundamental physical theory that applies to all possible physical phenomena, and in principle – not, of course, in practice – predicts how phenomena evolve in time.

[38] A false theory may, of course, make true approximate predictions. Thus Kepler's laws make false precise predictions about planetary motions, but true approximate predictions.

[39] See Maxwell (2017a, ch 8 and appendix 2) for a more detailed exposition of this solution to the problem of verisimilitude. For a discussion of attempts to solve the problem of verisimilitude that do not employ the notions of "true theory of everything" and "approximate derivation" see Zwart and Franssen (2007).

[40] Newton-Smith (1981, p. 14),

[41] These are somewhat idealized requirements for a theory to be accepted. In practice, the community of physicists may accept a new theory long before (1) has been established, on the basis of the conjecture that further scientific research will establish (1).

[42] See Maxwell (2017a, ch. 5 and appendix 1).

[43] See Maxwell (1984; 2004; 2014; 2019, ch. 5; 2020; 2021a; 2021b).