A Priori Conjectural Knowledge in Physics: The Comprehensibility of the Universe

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Abstract

The history of western philosophy is split to its core by a long-standing, fundamental dispute. On the one hand there are the so-called empiricists, like Locke, Berkeley, Hume, Mill, Russell, the logical positivists, A. J. Ayer, Karl Popper and most scientists, who hold empirical considerations alone can be appealed to in justifying, or providing a rationale for, claims to factual knowledge, there being no such thing as *a priori* knowledge – items of factual knowledge that are accepted on grounds other than the empirical. And on the other hand there are the so-called rationalists, like Descartes, Spinoza, Leibniz, Bradley, McTaggart, who hold that *a priori* knowledge does exist, and even plays a crucial role in science. This long-standing dispute is resolved by the line of thought developed in this essay. The empiricists were right to deny the existence of *a priori* knowledge where this means factual knowledge of apodictic certainty justified independently of any appeal to experience. They were wrong, however, to deny the existence of *a priori* knowledge where this means *conjectural* items of factual knowledge whose acceptance is justified independently of any appeal to experience. Science requires there to be *a priori* knowledge in this latter sense, and two items of such knowledge will be exhibited. In addition to resolving this empiricist/rationalist dispute, the essay also develops a new conception of science – aim-oriented empiricism – and solves the long-standing problem of what it means to say of a theory that it is *unified* or *explanatory*. Furthermore, aim-oriented empiricism does not just change our *conception* of science; it requires that *science itself* needs to change. Science needs to become much more like the 17th century conception of natural philosophy, intermingling consideration of testable theories with consideration of untestable metaphysical, epistemological and methodological ideas. The whole relationship between *science* and *the philosophy of science* is transformed. The philosophy of science, construed as the exploration and critical assessment of rival ideas about what the aims and methods of science ought to be, ceases to be a meta-discipline, and becomes an integral part of science – or natural philosophy – itself.

I

The *a priori* both must, and cannot possibly, play a role in physics. There are powerful arguments in support of both horns of this dilemma.

I begin with the well known arguments against *a priori* knowledge. All our knowledge about the world is acquired via experience. *A priori* knowledge about the world – knowledge based on an appeal to reason, independently of experience – is thus impossible. Reason is not some kind of intellectual searchlight which can, independently of observation and experiment, illuminate the world and provide us with infallible knowledge about it. All propositions which can be known to be true with certainty, in an *a priori* way, independently of experience – propositions like "either it is raining or it is not raining" or "all bachelors are unmarried" – are empty of factual content. And all propositions which have some factual content, which say something about the world, can only be known with some degree of uncertainty as a result of our experience of or interactions with the world – as a result of observation or experiment. As Einstein once put it "as far as propositions refer to reality, they are not certain; and as far as they are certain, they do not refer to reality".[1]

This unquestionably represents the orthodox view among scientists and philosophers of science. Not all philosophers would, however, be convinced by this bald statement of the case for the non-existence of *a priori* knowledge in science. Some might claim that the case for *a priori* knowledge is supported by Kripke's (1981) argument that identity statements with rigid designators are necessary – a statement such as that water is identical to H_2O being, according to Kripke, despite its factual appearance, nevertheless *necessary*. Kripke would not himself hold this; he makes it quite clear that necessity and the *a priori* must be sharply distinguished. And in any case, Kripke's case for the necessity of identity statements with rigid designators is, in my view, not valid, as I have argued in some detail elsewhere: see (Maxwell, 2001, appendix 2).

I should add, in passing, that the anti-*a priori* view, just indicated, can readily accommodate the thesis that necessary connections may exist between successive events or states of affairs. For we may hold that necessary connections exist but cannot be known to exist in an *a priori* fashion, with certainty. Elsewhere I have argued, along these lines, that necessary connections in nature are indeed possible, and that theoretical physics should be interpreted as improving our knowledge of their character: see Maxwell (1968; 1976a; 1985; 1988; 1998, pp. 141-155 & ch. 7).[2]

II

So much for the case *against* the *a priori* in science. The argument *for a priori* knowledge in science is not nearly so well known. It is an argument I have been advocating for over 30 years, but so far this advocacy has not had much impact. Nevertheless the argument is, I believe, decisive. It goes like this. Whenever a fundamental physical theory is accepted as a part of theoretical scientific knowledge there are always endlessly many rival theories which fit the available evidence just as well as the accepted theory. Consider, for example, Newtonian theory (NT). One rival theory asserts: everything occurs as NT asserts up till midnight tonight when, abruptly, an inverse cube law of gravitation comes into operation. A second rival asserts: everything occurs as NT asserts, except for the case of any two solid gold spheres, each having a mass of a thousand tons, moving in otherwise empty space up to a mile apart, in which case the spheres attract each other by means of an inverse cube law of gravitation. There is no limit to the number of rivals to NT that can be concocted in this way, each of which has all the predictive success of NT as far as observed phenomena are concerned but which makes different predictions for some as yet unobserved phenomena.[3] Such "patchwork quilt" theories can even be concocted which are *more* empirically successful than NT, by arbitrarily modifying NT, in just this entirely *ad hoc* fashion, so that the theories yield correct predictions where NT does not, as in the case of the orbit of Mercury for example (which very slightly conflicts with NT).[4] And quite generally, given any accepted physical theory, T, there will always be endlessly many "patchwork quilt" rivals which meet with all the empirical success of T, make untested predictions that differ from T, are empirically successful where T is ostensibly refuted, and successfully predict phenomena about which T is silent (as a result of independently testable and corroborated hypotheses being added on).

As most physicists and philosophers of physics would accept, *two* criteria are employed in physics in deciding what theories to accept and reject: (1) empirical criteria, and (2) criteria that have to do with the simplicity, unity or explanatory character of the theories in question. What the argument just indicated demonstrates is that (2) is absolutely indispensable, to such an extent that there are endlessly many theories empirically more successful than accepted theories, all of which are ignored because of their "patchwork quilt" character, their lack of unity.

Now comes the crucial point. In persistently accepting unifying theories (even though ostensibly refuted), and excluding infinitely many empirically more successful, unrefuted, disunified, "patchwork quilt", rival theories, science in effect makes a big assumption about the nature of the universe, to the effect that it is such that no disunified theory is true, however empirically successful it may appear to be for a time. Furthermore, without some such big assumption as this, the empirical method of science collapses. Science would be drowned in an infinite ocean of empirically successful disunified theories.[5]

If scientists only accepted theories that postulate atoms, and persistently rejected theories that postulate different basic physical entities, such as fields - even though many field theories can easily be, and have been, formulated which are even more empirically successful than the atomic theories - the implications would surely be quite clear. Scientists would in effect be assuming that the world is made up of atoms, all other possibilities being ruled out. The atomic assumption would be built into the way the scientific community accepts and rejects theories – built into the implicit *methods* of the community, methods which include: reject all theories that postulate entities other than atoms, whatever their empirical success might be. The scientific community would accept the assumption: the universe is such that no non-atomic theory is true.

Just the same holds for a scientific community which rejects all disunified or aberrant rivals to accepted theories, even though these rivals would be even more empirically successful if they were considered. Such a community in effect makes the assumption: the universe is such that no disunified theory is true. Or rather, more accurately, such a community makes the assumption: "the universe is such that no disunified theory is true *which is not entailed by a true unified theory (plus, possibly, true relevant initial and boundary conditions*)". (A true unified theory entails infinitely many approximate, true, disunified theories.) Let us call this assumption "physicalism".

On the face of it, physicalism constitutes *a priori* scientific knowledge. It is so firmly accepted that any theory which clashes with it is rejected *whatever its empirical success may be*. Far from being accepted on the basis of evidence, it is accepted, if anything, in the teeth of counter-evidence, in that, given any accepted unified theory there will always be endlessly many *disunified* rival theories which will not be considered for a moment because they clash with physicalism. The evidence constantly shouts "nature is disunified", and science calmly ignores this evidence and persists in accepting the unity of nature (physicalism) against the clamour of disunity. And furthermore, science must do this. Without the persistent acceptance of physicalism (explicit or implicit) science would be drowned in an ocean of absurd, "patchwork quilt" theories. (For earlier, and in some cases more detailed, expositions of this argument see: Maxwell, 1974; 1984, ch. 9; 1993; and especially 1998; 2004a, chs. 1 and 2, and appendix; and 1984, 2nd ed., 2007, ch. 14.)

That is the case *for a priori* scientific knowledge.

III

How is the dilemma with which we began to be resolved? This is not too difficult a question to answer. The argument against the *a priori* is against knowledge which can be established *with certainty* by reason independently of experience. The argument for the *a priori* is merely for knowledge which is accepted on grounds other than an appeal to experience, and which may well be *conjectural* in character. Thus in order to resolve the dilemma all we need do is agree that we have *a priori* knowledge in the sense of *conjectural* knowledge accepted on grounds other than evidence, but not in the sense of *indubitable* knowledge established by reason alone. All hope of having knowledge that has Kantian "apodictic certainty" must be abandoned.

It needs to be appreciated that this claim - that there is just one item of *conjectural a priori* knowledge, namely physicalism - though relatively modest, is nevertheless blatantly at odds with orthodoxy. It clashes with just about every philosophy of science one can think of put forward in the last century: logical positivism, inductivism, logical empiricism, hypothetico-deductivism, conventionalism, constructive empiricism, pragmatism, realism, induction-to-the-best-explanationism, Bayesianism, and the views of Duhem (1954), Popper (1959), Quine (1953), Kuhn (1962), Lakatos (1968) and most more recent authors on the subject. For all these views, diverse as they are in other respects, all accept that *no factual proposition about the world can be accepted permanently as a part of scientific knowledge independently of empirical considerations*. According to this view, the simplicity, unity or explanatory power of a theory may influence its acceptance in addition to empirical considerations, but not in such a way as to commit science permanently to the thesis that nature herself is simple, unified or comprehensible. This view (which elsewhere I have called *standard empiricism*) is starkly incompatible with the thesis that physicalism constitutes *a priori* knowledge.

If the above argument for *a priori* scientific knowledge is valid, then standard empiricism, and all the above views which incorporate standard empiricism (logical positivism, inductivism, etc.), must be rejected. But is the above argument valid? In what follows considerations will emerge which require that the argument is *revised*, but not *rejected*.

As it stands, the above argument for the *a priori* character of physicalism raises a number of questions. (1) What exactly does it *mean* to assert of a physical theory that it is unified? Once this question has been answered, we can go on to tackle the question (2) What ought physicalism to be interpreted to assert about the universe? The case for claiming that physicalism is an *a priori* conjectural presupposition of physics rests on the claim that physics only accepts unified theories: hence the need to answer (1) before we can answer (2). Closely related to (2) is the question: (3) What rationale is there for accepting physicalism as a part of scientific knowledge? And finally, and most germane to the subject of this essay, and this book, there is the question: (4) Is physicalism really wholly *a priori* in character? Can we not imagine circumstances in which science, or at least the pursuit of knowledge, would be possible even though physicalism is false and is rejected? Does not this suffice to establish that physicalism is not *a priori*? If it is not, is there any item of scientific knowledge that is wholly *a priori* in character, wholly untainted by the empirical?

The rest of this essay is devoted to answering these four questions in turn.

IV

(1) *What exactly does it mean to assert of a physical theory that it is unified?* This is a notorious, long-unsolved problem in the philosophy of science. Einstein recognized the problem but confessed he did not know how to solve it (Einstein, 1982, p. 23). J. J. C.

Smart once declared it to be one of the most important unsolved problems in the philosophy of science (Salmon, 1989, p. 4). Many attempts have been made at solving the problem, none satisfactory.[6] The main difficulty is that any given theory can be formulated in many different ways, some formulations being beautifully simple and "unified", others being horribly complex and "disunified". The crucial step that needs to be taken to solve the problem is to recognize that what matters is what a given theory asserts about the world. In assessing the simplicity or unity of the theory it is its *content* that is important; the form of the theory is irrelevant. What has made the problem so hard to solve is that those trying to solve it have been staring at the wrong thing, the theory itself, its linguistic or axiomatic structure, its pattern of derivations, when they should have been looking at *what the theory asserts about the world*.[7]

The solution to the problem is in fact implicit in the above argument for the *a priori* character of physicalism. There, a distinction was drawn between unified and "patchwork quilt", disunified theories. This is the heart of the matter. A unified theory is one which makes the same assertion - which specifies the same dynamical laws - throughout the range of phenomena to which it applies. A disunified theory is one which makes different assertions - which specifies different dynamical laws - in different regions of phenomena to which the theory applies. If a theory, T, specifies N distinct dynamical laws governing the evolution of phenomena in N distinct regions of phenomena, than T is disunified to degree N. For unity we require N = 1.

But there is an important complication. It turns out that there are *different* ways in which the content, the dynamical laws, can be different as we move from one range of phenomena to another - some of these ways being much more extreme than others. Here are eight increasingly mild kinds of disunity.

A dynamical physical theory, T, is disunified to degree N if and only if:

(1) T divides space-time up into N distinct regions, $R_1...R_N$, and asserts that the laws governing the evolution of phenomena are the same for all spacetime regions within each R-region, but are different in different R-regions.

(2) T postulates that, for distinct ranges of physical variables (other than position and time), such as mass or relative velocity, in distinct regions, $R_1,...R_N$ of the space of all possible phenomena, distinct dynamical laws obtain.

(3) In addition to postulating non-unique physical entities (such as particles), or entities unique but not spatially restricted (such as fields), T postulates, in an arbitrary fashion, N - 1 distinct, unique, spatially localized objects, each with its own distinct, unique dynamic properties.

(4) T postulates physical entities interacting by means of N distinct forces, different forces affecting different entities, and being specified by different force laws. (In this case one would require one force to be universal so that the universe does not fall into distinct parts that do not interact with one another.)

(5) T postulates N different kinds of physical entity, differing with respect to some dynamic property, such as value of mass or charge, but otherwise interacting by means of the same force.

(6) Consider a theory, T, that postulates N distinct kinds of entity (e.g. particles or fields), but these N entities can be regarded as arising because T exhibits some symmetry (in the way that the electric and magnetic fields of classical electromagnetism can be regarded as arising because of the symmetry of Lorentz invariance, or the eight gluons of

chromodynamics can be regarded as arising as a result of the local gauge symmetry of SU(3)).[8] If the symmetry group, G, is not a direct product of subgroups, we can declare that T is fully unified; if G is a direct product of subgroups, T lacks full unity; and if the N entities are such that they cannot be regarded as arising as a result of some symmetry of T, with some group structure G, then T is disunified.

(7) If (apparent) disunity of there being N distinct kinds of particle or distinct fields has emerged as a result of a series of cosmic spontaneous symmetry-breaking events, there being manifest unity before these occurred, then the relevant theory, T, is unified. If current (apparent) disunity has not emerged from unity in this way, as a result of spontaneous symmetry-breaking, then the relevant theory, T, is disunified.[9]

(8) According to GR, Newton's force of gravitation is merely an aspect of the curvature of spacetime. As a result of a change in our ideas about the nature of spacetime, so that its geometric properties become dynamic, a physical force disappears, or becomes unified with spacetime. This suggests the following requirement for unity: spacetime on the one hand, and physical particles-and-forces on the other, must be unified into a single self-interacting entity, U. If T postulates spacetime and physical "particles-and-forces" as two fundamentally distinct kinds of entity, then T is not unified in this respect.

For unity, in each case, we require N = 1. As we go from (1) to (5), the requirements for unity are intended to be accumulative: each presupposes that N = 1 for previous requirements. As far as (6) and (7) are concerned, if there are N distinct kinds of entity which are not unified by a symmetry, whether broken or not, then the degree of disunity is the same as that for (4) and (5), depending on whether there are N distinct forces, or one force but N distinct kinds of entity between which the force acts.

(8) introduces, not a new kind of unity, but rather a new, more severe way of counting different kinds of entity. (1) to (7) taken together require, for unity, that there is one kind of self-interacting physical entity evolving in a distinct spacetime, the way this entity evolves being specified, of course, by a consistent physical theory. According to (1) to (7), even though there are, in a sense, two kinds of entity, matter (or particles-and-forces) on the one hand, and spacetime on the other, nevertheless N = 1. According to (8), this would yield N = 2. For N = 1, (8) requires matter and spacetime to be unified into one basic entity (unified by means of a spontaneously broken symmetry, perhaps).

As we go from (1) to (8), then, requirements for unity become increasingly demanding, with (6) and (7) being at least as demanding as (4) and (5), as explained above.[10] It is important to appreciate, however, that (1) to (8) are all versions of the same basic idea that T is unified if and only if the content of T is the same throughout the range of possible phenomena to which it applies. When T is disunified, (1) to (8) specify *different* kinds of difference in the content of T in diverse regions of the space, S, of all possible phenomena to which T applies. Or, equivalently, (1) to (8) divide S into sub-regions in *different* ways, T having a different content in each sub-region.[11]

V

(2) *What ought physicalism to be interpreted to assert about the universe?* (3) *What rationale is there for accepting physicalism as a part of scientific knowledge?* Before I answer these two closely inter-related questions, I must first consider how the account of unity of theory just given both clarifies and complicates the argument for the *a priori* of section II. Two points in particular need to be made.

The first is this. Above it was more or less taken for granted that a single disunified theory cannot be turned into two or more unified theories merely by chopping it into a number of distinct theories, each of which is unified. If this assumption is incorrect, the methodological requirement that an acceptable theory must be unified is in danger of becoming one which can always be fulfilled quite trivially, by the simple device of chopping any disunified theory into many unified theories. For theories that are disunified in ways (1) to (3), the assumption is valid. Thus a theory disunified in space and/or time cannot be turned into a number of unified theories, each restricted to specific regions of space and/or time, since physical theories so restricted may be deemed to be disunified just because of that arbitrary restriction. In the case of a theory disunified in a type (4) or (5) way, however, it would be possible, so it would seem, to chop the theory into a number of distinct theories, each postulating just one kind of force, or one kind of entity, and thus each being unified in a type (4) or type (5) way.

In order to exclude this trivial manoeuvre, the methodological requirement that a theory must be unified to be acceptable must be reformulated so that it applies to the whole of fundamental theory in physics - to all those theories which, in sum, apply in principle to all physical phenomena. Today, this sum consists of the so-called standard model (the quantum field theory of fundamental particles and forces) and general relativity.[12] (If a range of phenomena has no fundamental theory associated with it, then laws governing the phenomena must be included among fundamental physical theory.) The methodological requirement of theoretical unity can now be stated like this: A new fundamental physical theory, in order to be acceptable on non-empirical grounds, must be such that, when added to the totality of fundamental physical theory (perhaps replacing one or more precursor theories), the disunity of this totality is decreased (or, as a bare minimal requirement, not increased).

The second point is this. The account of unity of theory of the last section makes clear that, even though this involves a single basic idea (a theory is unified if the dynamical laws it specifies are *the same* for all the phenomena it predicts), nevertheless there are at least eight *different* ways in which dynamical laws can differ, some of these differences being more serious, more substantial, than others. Unity of theory is, as it were, an eight-dimensional concept (at least). In assessing the disunity of a theory of everything, T, we must first assess the worst kind of disunity it suffers from, M = 8, 7, … 1, and then assess its degree of disunity, N = 1, 2, …, so that disunity is fixed by two numbers, (M,N). [I have adopted the convention that (8,2) = (7,1).] The smaller M is, the more serious the kind of disunity; the larger N is, the greater the degree of disunity. For perfect unity, we require (8,1).

The argument for the *a priori* of section II needs to be regarded, then, as establishing that physics presupposes physicalism interpreted to assert: the universe is such that the true theory of everything, T, has a less serious *kind* of disunity than the totality of current accepted fundamental physical theory (plus phenomena where there is no theory), and/or a lower *degree* of disunity (or, at the very least, a *kind* of disunity no more serious, and a *degree* of unity no greater, than current fundamental theory).

This clarifies the argument of section II. But there is a complication. The argument establishes that physics makes metaphysical assumptions,[13] but not that these assumptions are *a priori*. As physics advances, and greater and greater unity of accepted fundamental physical theory is achieved, so physicalism is repeatedly reinterpreted so that it asserts underlying dynamic unity in stronger and stronger senses. But if physicalism is to be revised in this way, in the light of empirical research, how can it be regarded as *a priori*?[14]

I defer discussion of what, exactly, is *a priori* in physics, until later, and consider first the question of what physics *ought* to be taken as presupposing, in the light of what has been said so far, and what reasons there are for adopting such a supposition.

There are six considerations – six methodological principles – which must be taken into account in deciding what physics ought to be taken to be assuming about the nature of the universe – what metaphysical assumption(s) it ought to be taken to be making. I now specify these six considerations in turn, and in each case specify the metaphysical thesis that is picked out. It is vital to appreciate that the following considerations provide grounds for holding that the relevant theses should be *accepted* as a part of scientific knowledge granted that our aim is to discover truth, but do not provide grounds for holding that the theses themselves are *true*.

1. This first consideration is the one we have already encountered above. Physics should accept the least substantial thesis that is implicit in the persistent acceptance of unified theories when empirically more successful disunified theories are always available. This picks out Physicalism(M,N), where M corresponds to a kind of disunity less severe than (or equal to) the kind of disunity of the totality of accepted fundamental physical theory, and N is less than (or equal to) the degree of disunity of the totality of accepted theory.

2. Physics should accept that metaphysical thesis which must be true if the acquisition of knowledge is to be possible at all – knowledge of our local environment required in order to make life possible. This picks out the thesis: the universe is such that we can continue to acquire knowledge of our local environment sufficient to make life possible.

3. Assumptions that are substantial, problematic, influential and implicit need to be made explicit so that they can be critically assessed and so that alternatives can be considered, in the hope that the assumptions can be *improved*. In the case physics, that assumption needs to be made explicit which is implicit in the *persistent* choice of unifying theories when this persistence is *pushed to the limit*. The implicit assumption inherent in *persistently* accepting increasingly unifying theories, when pushed to the limit, is that there is underlying dynamic unity in all natural phenomena – that is, physicalism(8,1). The persistent search for greater and greater unity of theory can only be satisfied if physicalism(8,1) is true. (This is not an argument for the *truth* of physicalism(8,1). Rather it is an argument for accepting physicalism(8,1) – granted our aim is to discover truth – so that this thesis, the extreme implicit presupposition of our methodology, may be subjected to maximum critical scrutiny, giving maximum hope of improvement. If the search for unity must ultimately fail because physicalism(8,1) is false, the sooner we discover this fact, and find an improved rival thesis, the better.)

4. Given that some kind of metaphysical thesis must be accepted by physics, that thesis is to be preferred which (if true) holds out the greatest hope of scientific progress. On these grounds, physicalism (8,1) is to be preferred to physicalism(M,N), where (M,N) are the values of currently accepted fundamental physical theory (since the latter thesis holds out no hope of progress in theoretical physics at all).

5. Again, given that some kind of metaphysical thesis must be accepted by physics, that thesis is to be preferred which has supported the most empirically fruitful scientific research programme. This consideration, again, picks out physicalism(8,1). All the great contributions to theoretical physics have brought greater theoretical unity to the subject,

and can thus be regarded as constituting stepping stones towards the discovery of underlying dynamic unity in nature. From the 17th century to today, theoretical physics constitutes an astonishingly empirically successful research programme progressively moving towards capturing a *unified* theory applicable in principle to *all* phenomena. Unification, in senses (1) to (8) above, is the persistent theme of all the great theoretical revolutions in physics. Thus Newtonian theory (NT) unifies Galileo's laws of terrestrial motion and Kepler's laws of planetary motion (and much else besides): this is unification in senses (1) to (3). Maxwellian classical electrodynamics, (CEM), unifies electricity, magnetism and light (plus radio, infra red, ultra violet, X and gamma rays): this is unification in sense (4). Special relativity (SR) brings greater unity to CEM, in revealing that the way one divides up the electromagnetic field into the electric and magnetic fields depends on one's reference frame: this is unification in sense (6). SR is also a step towards unifying NT and CEM in that it transforms space and time so as to make CEM satisfy a basic principle fundamental to NT, namely the (restricted) principle of relativity. SR also brings about a unification of matter and energy, via the most famous equation of modern physics, $E = mc^2$, and partially unifies space and time into Minkowskian space-time. General relativity (GR) unifies space-time and gravitation, in that, according to GR, gravitation is no more than an effect of the curvature of space-time – a step towards unification in sense (8). Quantum theory (QM) and atomic theory unify a mass of phenomena having to do with the structure and properties of matter, and the way matter interacts with light: this is unification in senses (4) and (5). Quantum electrodynamics unifies QM, CEM and SR. Quantum electroweak theory unifies (partially) electromagnetism and the weak force: this is (partial) unification in sense (7). Quantum chromodynamics brings unity to hadron physics (via quarks) and brings unity to the eight kinds of gluons of the strong force: this is unification in sense (6). The standard model (SM) unifies to a considerable extent all known phenomena associated with fundamental particles and the forces between them (apart from gravitation): partial unification in senses (4) to (7). The theory unifies to some extent its two component quantum field theories in that both are locally gauge invariant [the symmetry group being $U(1) \times SU(2) \times SU(3)$]. All the current programmes to unify SM and GR known to me, including string theory or M-theory, seek to unify in senses (4) to (8).[15]
6. Finally, physics has made progress as a result of putting forward bold conjectures that are then subjected to fierce attempted refutation – precisely formulated theories that have immense empirical content and that are then subjected to severe empirical scrutiny. Just the same procedure should operate in the essential *metaphysical* domain of physics. Here too, precisely formulated, bold conjectures should be put forward which are then subjected to fierce critical scrutiny – the more precise and bolder the better, since these are all the more potentially vulnerable (if false) to criticism. This consideration favours physicalism(8,1) over physicalism(M,N), the latter being messy and indefinite (given uncertainties about dark matter and quintessence).

What is striking about these six considerations is that they point in different directions. Some (1 and 2) point in the direction of accepting the most modest, least substantial theses capable of fulfilling the specified role. Others (3 to 6) point in the direction of accepting one of the most immodest, substantial theses conceivable, namely physicalism(8,1). How can these conflicting desiderata all be satisfied?

The solution is to see physics as accepting, not just *one* thesis, but a *hierarchy* of theses. At the top of the hierarchy there is an insubstantial thesis which must be true if physics, or the acquisition of knowledge more generally, is to be possible at all. As one goes down the hierarchy, the theses become increasingly substantial, potentially increasingly fruitful for the growth of knowledge, but also increasingly likely to be false, and thus increasingly in need of sustained critical scrutiny. One possibility is to take, as this hierarchy, the eight versions of physicalism corresponding to the eight types of unity specified in section IV above. At the top there is the relatively insubstantial thesis physicalism(1,1), which asserts merely that the true theory of everything is unified in a type (1) way, to degree 1. Near the bottom of the hierarchy there is the very substantial thesis physicalism(8,1), which asserts that the true theory of everything is unified in a type (8) way, to degree 1. For a more detailed exposition and discussion of this version of the hierarchical view see Maxwell (2004d).

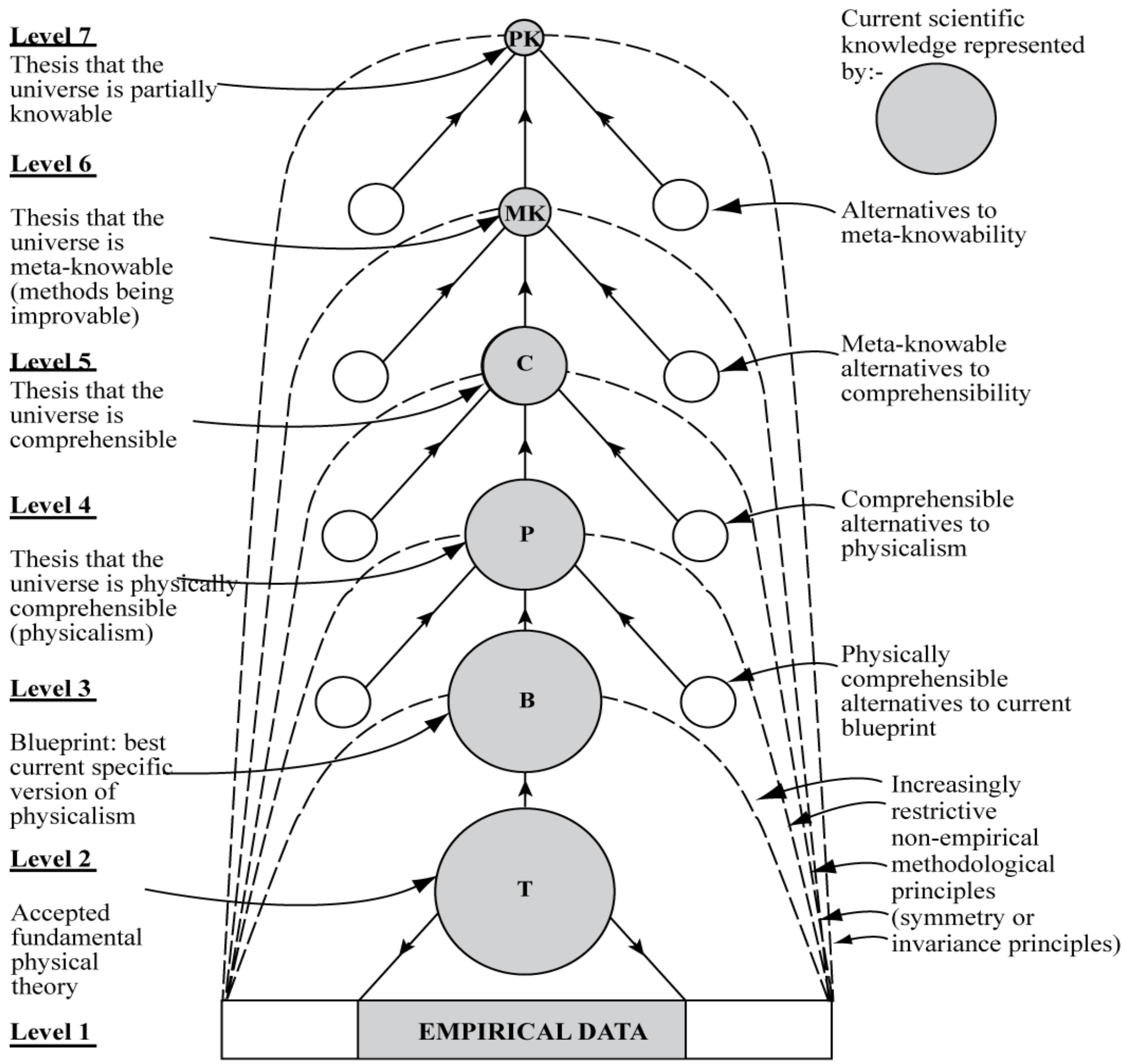

Diagram: Aim-Oriented Empiricism (AOE)

The problem with this version of the hierarchical view is that possibilities can be imagined which would render all eight versions of physicalism false, and yet life, the acquisition of knowledge, and even a kind of science, might still be possible. Perhaps God is ultimately in charge of the universe, and all versions of physicalism are false because God on occasions arranges for miracles to occur. Perhaps the universe is comprehensible but not *physically* comprehensible. Perhaps the universe is not comprehensible, all eight versions of physicalism being false, but knowledge can still be acquired. In order to take these possibilities into account, we need to adopt the following more general version of the hierarchical view: see diagram.

At the top of the hierarchy there is the relatively insubstantial assumption that the universe is such that we can acquire some knowledge of our local circumstances. If this assumption is false, we will not be able to acquire knowledge whatever we assume. We are justified in accepting this assumption permanently as a part of our knowledge, even though we have no grounds for holding it to be true. As we descend the hierarchy, the assumptions become increasingly substantial and thus increasingly likely to be false. At level 6 there is the more substantial thesis that there is some rationally discoverable thesis about the nature of the universe which, if true and if accepted, makes it possible progressively to improve methods for the improvement of knowledge. "Rationally discoverable", here, means at least that the thesis is not an arbitrary choice from infinitely many analogous theses. At level 5 we have the even more substantial thesis that the universe is *comprehensible* in some way or other, whether physically or in some other way. This thesis asserts that the universe is such that there is *something* (God, tribe of gods, cosmic goal, physical entity, cosmic programme or whatever), which exists everywhere in an unchanging form and which, in some sense, determines or is responsible for everything that changes (all change and diversity in the world in principle being explicable and understandable in terms of the underlying unchanging *something*). A universe of this type deserves to be called "comprehensible" because it is such that everything that occurs, all change and diversity, can in principle be explained and understood as being the outcome of the operations of the one underlying *something*, present throughout all phenomena. At level 4 we have the still more substantial thesis that the universe is *physically* comprehensible in some way or other. This asserts that the universe is made up one unified self-interacting physical entity (or one kind of entity), all change and diversity being in principle explicable in terms of this entity. What this amounts to is that the universe is such that some yet-to-be-discovered unified physical theory of everything is true. In terms of the terminology indicated above, this thesis is physicalism(8,1). At level 3, we have an even more substantial thesis, the best, currently available specific idea as to how the universe is physically comprehensible. This asserts that everything is made of some specific kind of physical entity: corpuscle, point-particle, classical field, quantum field, convoluted space-time, string, or whatever. Given the historical record of dramatically changing ideas at this level, and given the relatively highly specific and substantial character of successive assumptions made at this level, we can be reasonably confident that the best assumption available at any stage in the development of physics at this level will be false, and will need future revision. Here, ideas evolve with evolving knowledge. At level 2 there are the accepted fundamental theories of physics, currently general relativity and the standard model. Here, if anything, we can be even more confident that current theories are false, despite their immense empirical success. This confidence comes partly from the vast empirical content of these theories, and partly from the historical record. The greater the content of a proposition the more likely it is to be false; the fundamental theories of physics, general relativity and the standard model have such vast empirical content that this in itself almost guarantees falsity. And the historical record backs this up; Kepler's laws of planetary motion, and Galileo's laws of terrestrial motion are corrected by Newtonian theory, which is in turn corrected by special and general relativity; classical physics is corrected by quantum theory, in turn corrected by relativistic quantum theory, quantum field theory and the standard model. Each new theory in physics reveals that predecessors are false. Indeed, if the level 4 assumption is correct, then all current physical theories are false, since this assumption asserts that the true physical theory of everything is unified, and the totality of current fundamental physical theory, general relativity plus the standard model, is notoriously disunified. Finally, at level 1 there are accepted empirical data, low level, corroborated, empirical laws.[16]

The idea is to separate out what is most likely to be true, and not in need of revision, at and near the top of the hierarchy, from what is most likely to be false, and most in need of criticism and revision, near the bottom of the hierarchy. Evidence, at level 1, and assumptions high up in the hierarchy, are rather firmly accepted, as being most likely to be true (although still open to revision): this is then used to criticize, and to try to improve, theses at levels 2 and 3 (and perhaps 4), where falsity is most likely to be located.

In order to be acceptable, an assumption at any level from 6 to 3 must (as far as possible) be compatible with, and a special case of, the assumption above in the hierarchy; at the same time it must be (or promise to be) empirically fruitful in the sense that successive accepted physical theories increasingly successfully accord with (or exemplify) the assumption. At level 2, those physical theories are accepted which are sufficiently (a) empirically successful and (b) in accord with the best available assumption at level 3 (or level 4). Corresponding to each assumption, at any level from 7 to 3, there is a methodological principle, represented by sloping dotted lines in the diagram, requiring that theses lower down in the hierarchy are compatible with the given assumption.

When theoretical physics has completed its central task, and the true theory of everything, T, has been discovered, then T will (in principle) successfully predict all empirical phenomena at level 1, and will entail the assumption at level 3, which will in turn entail the assumption at level 4, and so on up the hierarchy. As it is, physics has not completed its task, T has not (yet) been discovered, and we are ignorant of the nature of the universe. This ignorance is reflected in clashes between theses at different levels of AOE. There are clashes between levels 1 and 2, 2 and 3, and 3 and 4. The attempt to resolve these clashes drives physics forward.

In seeking to resolve these clashes between levels, influences can go in both directions. Thus, given a clash between levels 1 and 2, this may lead to the modification, or replacement of the relevant theory at level 2; but, on the other hand, it may lead to the discovery that the relevant experimental result is not correct for any of a number of possible reasons, and needs to be modified. In general, however, such a clash leads to the rejection of the level 2 theory rather than the level 1 experimental result; the latter are held onto more firmly than the former, in part because experimental results have vastly less empirical content than theories, in part because of our confidence in the results of observation and direct experimental manipulation (especially after expert critical examination). Again, given a clash between levels 2 and 3, this may lead to the rejection of the relevant level 2 theory (because it is disunified, *ad hoc*, at odds with the current metaphysics of physics); but, on the other hand, it may lead to the rejection of the level 3 assumption and the adoption, instead, of a new assumption (as has happened a number of times in the history of physics, as we have seen). The rejection of the current level 3 assumption is likely to take place if the level 2 theory, which clashes with it, is highly successful empirically, and furthermore has the effect of increasing unity in the totality of fundamental physical theory overall, so that clashes between levels 2 and 4 are decreased. In general, however, clashes between levels 2 and 3 are resolved by the rejection or modification of theories at level 2 rather than the assumption at level 3, in part because of the vastly greater empirical content of level 2 theories, in part because of the empirical fruitfulness of the level 3 assumption (in the sense indicated above).

It is conceivable that the clash between level 2 theories and the level 4 assumption might lead to the revision of the latter rather than the former. This happened when Galileo rejected the then current level 4 assumption of Aristotelianism, and replaced it with the idea that "the book of nature is written in the language of mathematics" (an early precursor of our current level 4 assumption). The whole idea, however, is that as we go up the hierarchy of assumptions we are increasingly unlikely to encounter error, and the need for revision. The higher up we go, the more firmly assumptions are upheld, the more resistance there is to modification.

This hierarchical view, called by me *aim-oriented empiricism* (AOE), does justice to all six of the conflicting considerations spelled out above. But there is more to it that that. Its real merit is that it makes explicit metaphysical assumptions implicit in the manner in which physical theories are accepted and rejected, and which, at the same time, facilitates the critical assessment and improvement of these assumptions with the improvement of knowledge, criticism being concentrated where it is most needed, low down in the hierarchy. Within a framework of relatively insubstantial, unproblematic and permanent assumptions and methods (high up in the hierarchy), much more substantial, problematic assumptions and associated methods (low down in the hierarchy) can be revised and improved with improving theoretical knowledge. There is something like positive feedback between improving knowledge and improving (low-level) assumptions and methods – that is, knowledge-about-how-to-improve-knowledge. Science adapts its nature, its assumptions and methods, to what it discovers about the nature of the universe. This, I suggest, is the nub of scientific rationality, and the methodological key to the great success of modern science.

In summary, then, the argument in support of AOE is this. Some kind of more or less substantial metaphysical assumption is implicitly accepted by physics given that unifying theories are persistently favoured *against the evidence*. This metaphysical assumption is very likely to be false. We need to array metaphysical assumptions in such a way that we subject them to maximum critical scrutiny, criticism being concentrated where it is most likely to be needed – those theses being favoured either which must be true for the acquisition of knowledge to be possible at all, or which are most fruitful from the standpoint of promoting the growth of knowledge. The hierarchical structure of AOE succeeds uniquely well in doing what is required. No other view facilitates *improvement* of metaphysical assumptions and associated methods in response to the improvement of scientific knowledge as well as AOE does. (I put the matter like this to challenge the reader to think up something better.)

VI

Granted AOE, as depicted in the diagram, what has become of *a priori* knowledge in physics? If "*a priori* knowledge" is to mean anything, it must mean at least, surely, "knowledge accepted independently of evidence". The whole point of AOE, however, is that the metaphysical theses in the hierarchy are *revised* in the light, in part, of evidence. This would seem to preclude any of these theses constituting *a priori* knowledge.

But this is not the case. The top two theses in the hierarchy, at levels 7 and 6, are accepted on grounds entirely independent of empirical considerations, revisable, if at all, in the light of improved non-empirical arguments only. These constitute *a priori* items of (conjectural) scientific knowledge. Three arguments establish this point.

(1) The level 7 thesis of partial knowability is a thesis that science, or the pursuit of knowledge more generally, is justified in accepting permanently, whatever may occur. Accepting this thesis as a part of knowledge can only aid, and can never impede, the acquisition of knowledge, in any circumstances whatsoever. If the thesis is false, then we cannot acquire knowledge, and hence cannot live, whatever we assume. This thesis is an authentic item of *a priori* (conjectural) knowledge: its acceptability is entirely unaffected by any empirical consideration. (This is, of course, not an argument for the *truth* of the thesis of partial knowability, but only for its *acceptance* as a permanent item of knowledge granted our aim is to acquire knowledge of factual truth, in so far as we can.)
(2) AOE demands that there is an item of *a priori* knowledge high up in the hierarchy. Without this, AOE collapses. For, if all the theses in the hierarchy were accepted on the basis of empirical considerations (of the kind indicated by 2 to 5 of section V above) then, whatever hierarchy is accepted on this basis, there will always be many (in principle infinitely many) *rival* hierarchies, composed of rival *disunified* theses, just as acceptable on purely empirical grounds. For example, if NT is accepted at level 2, and NT* is some equally empirically successful disunified variant of NT, then a rival hierarchy of disunified metaphysical theses can easily be concocted which favours NT* and excludes NT as unacceptable. The argument of section II above simply reappears, in a slightly modified form, with full force. Given any empirically successful, accepted theory, T, there will be infinitely many equally empirically successful (or more empirically successful) disunified rivals, T_1*, T_2* … T_∞*, each with its associated hierarchy of appropriately disunified metaphysical theses, {M_1*}, {M_2*} … {M_∞*}. Whatever purely *empirical* arguments there are for accepting T and its associated hierarchy of theses {M}, these will be echoes by equally valid, purely empirical arguments for favouring T_1* and {M_1*}, T_2* and {M_2*} … and T_∞* and {M_∞*}. AOE, in short, collapses. This collapse can only be avoided if a thesis is accepted, high up in the hierarchy of AOE, on entirely *a priori*, non-empirical grounds – this thesis being such that it rules out all *disunified* rival hierarchies, and renders only one unified hierarchy acceptable (once empirical considerations are taken into account as well). The thesis that performs this function is

the level 6 thesis of meta-knowability. This thesis asserts that there is some "rationally discoverable" metaphysical thesis which, if accepted, leads to improved methods for the improvement of knowledge. "Rationally discoverable" means that the thesis in question is not an arbitrary choice from infinitely many analogous theses. The level 5 thesis of perfect comprehensibility satisfies this requirement. Disunified rivals – theses that assert "broken" comprehensibility (some phenomena being incomprehensible, or phenomena occurring in accordance with two or more distinct pattern of comprehensibility incapable of being unified into *one* unified pattern of comprehensibility) fail to satisfy the requirement. These theses, given the level 6 thesis of meta-knowability, are unacceptable because they are *not* rationally discoverable. Each is an arbitrary choice from infinitely many analogous theses (the disunified elements being adjustable in infinitely many different ways, in the sort of way we saw in section II above).

Given the fundamental role that this level 6 thesis of meta-knowability has within AOE, it is clearly of crucial importance to know what the non-empirical, *a priori* grounds are for accepting this thesis as a part of scientific knowledge. This issue will be discussed in a moment.

(3) If AOE is acceptable, it must be possible to solve the problem of induction within its framework – in so far as it is possible to solve the problem at all. There is an elementary argument which seems to show that the problem of induction cannot possibly be solved granted AOE – at least if AOE appeals only to empirical considerations in justifying acceptance of theses at various levels in the hierarchy. Any attempt to solve the problem of induction in this way must be circular. For it involves appealing to metaphysical theses in order to justify acceptance of scientific theories, and then appealing to scientific theories in order to justify acceptance of metaphysical theses. A purely empirical version AOE can only provide some slightly more intricate variant of such a hopelessly viciously circular argument, as a candidate for the solution to the problem of induction. The hopeless invalidity of this kind of circular argument is highlighted by the argument spelled out in (2) above. Given that acceptance of NT is justified (in part) by an appeal to the unified thesis of physicalism at level 4, acceptance of any equally empirically successful NT* can be justified equally well by an appeal to an appropriately disunified variant of the level 4 thesis of physicalism. In order to solve the problem of induction, in short, it is essential to acknowledge the existence of *a priori* knowledge. We require there to be a metaphysical thesis which is accepted for purely non-empirical, *a priori* reasons. This is the level 6 thesis of meta-knowability.[17]

What exactly ought this crucial level 6 thesis to be taken to assert, and what are the non-empirical grounds for accepting it as a part of scientific knowledge? In order to answer this question we need first to answer another: What is the least substantial thesis that must be true if AOE is to be implementable?[18] Actually, we need to answer a somewhat broader question: What is the least substantial thesis that must be true if *generalized* AOE (GAOE) is to be implementable? I have used "AOE" to refer to the hierarchy of theses indicated in the diagram above. But in order to discuss the *a priori* character of the level 6 thesis of meta-knowability, we need to consider much broader possibilities. Physicalism might be false, but the level 5 comprehensibility thesis might be true, a hierarchy of theses might be acceptable, and it might be possible to improve aims and methods in the light of improving knowledge in the way so characteristic of AOE.

This might be the case even if the level 5 thesis of comprehensibility is false. We need in short to generalize AOE to take into account such possibilities. "Implementable" in the above question does not mean that GAOE meets with success, just that any specific version of GAOE, with some appropriate thesis M at level 5, is not sabotaged by some grossly disunified, *ad hoc* variant of M being true. AOE, or GAOE more generally, is only implementable if the falsity of grossly disunified, *ad hoc* rivals to any acceptable level 5 thesis can be taken for granted.

It is at once clear, in broad outline at least, what the level 6 thesis of meta-knowability must assert: *No grossly disunified, ad hoc variant of a potentially acceptable level 5 thesis is true*. We do not require that meta-knowability asserts that some acceptable level 5 thesis is true, merely that all grossly *ad hoc* variants are false.

At once at least three questions arise about this thesis. I indicate, briefly, how, in my view, these questions are to be answered.

1. How do we decide whether a thesis, M, is a candidate level 5 thesis? Answer: M must either be the thesis that the universe is comprehensible, or some rival thesis about the overall nature of the universe of comparable generality that has the potential for supporting GAOE research. If some thesis M* is a special case of a more general thesis M that satisfies this condition, then M is the candidate level 5 thesis, and not M*.

2. Are there rivals to the level 5 thesis of comprehensibility that amount to candidate level 5 theses? Answer: Two examples are as follows. M_1: the universe is such that theoretical physics, in order to make progress, must go through an endless series of theoretical revolutions, each revolution being such that, after it, the number of distinct fundamental physical theories goes up by one. M_2: there are three fundamental forces governing all phenomena, each being such that its nature can be specified increasingly accurately as a result of theoretical revolutions, infinitely many such revolutions being required, however, before any force can be specified precisely. In view of the answer to 1, however, M_1 and M_2 should perhaps be regarded as different versions the level 5 thesis: the universe is such that infinitely many theoretical revolutions in physics are required before the true theory of everything can be formulated, the series of revolutions having associated with it some simple series of numbers, each being the number of distinct theories required for that revolution.[19]

3. How do we distinguish unambiguously between candidate level 5 theses that are, and are not, grossly disunified and *ad hoc*? Answer: Relevant here are some of the points made in section IV above concerning the unity of physical theory. Thus, in order to distinguish between unified and grossly disunified or *ad hoc* candidate level 5 theses we must attend to the *content* of these theses, to what they assert about the world, and not to their linguistic form. Let us now, to begin with, restrict our attention to candidate level 5 theses that assert that the universe is physically comprehensible, either in a grossly disunified way or not in a grossly disunified way. How is the line between these possibilities to be drawn? In order to answer this question, we need to appeal to the different kinds of disunity of physical theory, distinguished in section IV above. The true physical theory of everything, T, might be disunified in ways (4) to (7), and still AOE science (or GAOE science) might be possible – as long as the degree of disunity, N, is not too large. What undermines AOE science is T being disunified in ways (1) and (2). We might call this severe kind of disunity "aberrance". If nature is aberrant, then the laws of nature can, at any instant, be transformed utterly into something quite different, there

being no possibility of predicting beforehand that this transformation will take place.[20] It is this severe kind of disunity, or aberrance, that we must be able to exclude from consideration if AOE science is to be possible. What about disunity of type (3)? In some cases, given a physical universe disunified in a type (3) way, it might still be possible to do AOE science: this possibility cannot, it seems to me, be excluded on *a priori* grounds. We are led, then, to interpret "grossly disunified" to mean "aberrant", i.e. "disunified in ways (1) or (2)". I assume that this notion of "aberrance", as it arises in the context of physical theory and physical comprehensibility, can be generalized so that it applies equally to theses that assert that the universe is more or less comprehensible in non-physical ways, or that the universe is such that GAOE is implementable because of some level 5 thesis other than that of comprehensibility.

The conclusion, then, is this. The level 6 thesis of meta-knowability is to be interpreted as asserting: The universe is such that no candidate level 5 thesis that is *aberrant* [i.e. disunified in ways (1) or (2)] is true.

GAOE, and thus AOE, become possible if – but only if – meta-knowability, so defined, is acceptable on *a priori* grounds. But what are these *a priori* grounds? Here are three arguments intended to establish that meta-knowability is acceptable as an item of *a priori* scientific knowledge.

1. Granted that there is *some* kind of general feature of the universe which makes it possible for us to acquire knowledge of our local environment (as guaranteed by the thesis at level 7), it is reasonable to suppose that we do not know all that there is to be known about what the *nature* of this general feature is. It is reasonable to suppose, in other words, that we can improve our knowledge about the nature of this general feature, thus improving methods for the improvement of knowledge. Not to suppose this is to assume, arrogantly, that we already know all that there is to be known about how to acquire new knowledge. Granted that learning is possible (as guaranteed by the level 7 thesis), it is reasonable to suppose that, as we learn more about the world, we will learn more about how to learn. Granted the level 7 thesis of partial knowability, in other words, meta-knowability is a reasonable conjecture – even if we have so far failed to improve our methods for improving knowledge.

2. If the universe is *aberrant*, in the sense explicated above then, at any given moment, there can be no rationale for favouring one factual hypothesis or law as a basis for action over another. For, if the universe is aberrant, anything may happen at any moment. There will always be aberrant theories - empirically more successful than non-aberrant rivals - which predict that an aberrant event will occur at the next instant, whatever we may do. Empirical considerations favour the acceptance of such an aberrant theory at any instant, and if it is accepted that the universe is, in general, aberrant, no grounds exist for rejecting such a theory. In order for knowledge, and life, to be possible, the thesis that the universe is aberrant must be rejected.

3. Accepting meta-knowability can only help, and can never, in any circumstances, harm the pursuit of knowledge. For even if phenomena occur which appear to be aberrant, it can never help the pursuit of knowledge to accept, or to entertain as a possibility, that the universe is aberrant. Once this is accepted, or allowed as a possibility, the rationale for rejecting empirically successful aberrant theories disappears, and the pursuit of knowledge is sabotaged by a flood of empirically successful aberrant theories, in the kind of way discussed in section II above. Even if phenomena occur which appear to be aberrant, the pursuit of knowledge requires that it is assumed that there is some

underlying, as yet undiscovered, non-aberrant cause for the ostensibly aberrant phenomena.

Considerations 2 and 3 are strengthened, at least as far as the exclusion of type (1) aberrant theses is concerned, once it is recognized that anti-Humean necessary connections between successive events are possible. Suppose, to begin with, that Hume is right and no meaning can be given to the idea that necessary connections can obtain between successive states of affairs. In this case there does not seem to be such a big difference between a universe in which the same laws govern all phenomena at all times and a universe in which there is a slight, inexplicable change in the laws at some definite time. For, if Hume is right, there can be no explanation as to why laws are obeyed by natural phenomena. Deriving laws from more general laws just increases the mystery. Anything might happen at any moment, and it would seem just as big a mystery that phenomena occur in accordance with the same laws *at all times*, as that phenomena occur in accordance with same laws at all times *except for a slight change in the laws at some given time*. Grant, now, that Hume is wrong, and it *is* meaningful and possible that that which exists at one instant determines necessarily (deterministically or probabilistically) what exists at the next instant: see Maxwell (1968; 1976a; 1985; 1988; 1998, pp. 141-155 & ch. 7) for the demonstration that this is indeed the case.[21] Granted this, there *is* now an explanation as to why phenomena occur in accordance with laws: it is that the physical entities of which the universe is composed possess necessitating properties which determine that the laws are obeyed. If these entities exist with these properties, then the laws *must* be obeyed. Granted that we live in a universe which seems to exhibit lawfulness, as our universe does, it would be absurd, profoundly irrational indeed, to believe that nature will continue to be lawful and at the same time deny that necessitating properties exist which would explain why lawfulness does exist. But if there is an inexplicable, type (1) change in the laws at some specific time, this establishes that necessitating properties do not exist. Accepting that such a change has occurred would involve abandoning the idea that there exists something, in the constitution of things, that is responsible for the continuing lawfulness of nature. Anything might happen at any moment, and the persistent lawfulness of nature would be a mystery. There would be no rationale for choosing one set of factual hypotheses as a basis for action in preference to any other. The price that must be paid for acknowledging that the laws of nature have inexplicably changed, in a type (1) way, at some instant is, in other words, that one has to abandon the idea that what exists at one instant determines what exists next, and thus abandon the idea that there can be a rational basis for action. This provides additional grounds for rejecting *a priori* any thesis disunified in a type (1) way – a thesis that postulates an inexplicable change in the laws of nature at some specific time.

What if empirical science seems to establish aberrance, of type (2) let us say, on very firm empirical grounds? If some specific physical state of affairs is brought into existence, basic physical laws seem to change, and this effect occurs repeatedly, and resists all attempts at theoretical (i.e. non-aberrant, unifying) explanation. Should not meta-knowability be rejected in these circumstances? The answer is No. Meta-knowability should continue to be accepted, and the incompatibility between accepted theory, at level 2, and meta-knowability, at level 6, should be noted, and attempts to eliminate it by the development of new theory should continue. Incompatibility between levels is, as I have already noted, a standard feature of AOE. It exists in the current version of AOE, in that level 2 is incompatible with levels 4 and 5.

These three arguments for accepting meta-knowability as a part of scientific knowledge on *a priori* grounds are rather weak, and may well be challenged. It is important to appreciate, however, that unless meta-knowability (defined more or less as above) *is* accepted as a part of theoretical scientific knowledge on *a priori* grounds, AOE science becomes impossible. The three arguments I have given seem to me to be just about the best that can be given in support of the *a priori* status of meta-knowability.[22]

There are, then, two theses which deserve to be accepted as a part of scientific knowledge on *a priori* grounds: the level 7 thesis of partial knowability, and the level 6 thesis of meta-knowability.

I conclude this section by remarking that "*a priori*" may be interpreted in a more liberal, relational manner, the outcome being that more theses emerge as having "*a priori*" status. The arguments above have assumed that if a thesis has to be accepted as a part of knowledge if the pursuit of knowledge is to be possible at all, then that thesis deserves to be accepted on *a priori* grounds (even if there are no arguments for the truth of the thesis). We may, however, interpret "*a priori*" somewhat differently, so that a thesis is *a priori* if its truth is required for the success of *physics*, or the possibility of *science*. Thus, if theoretical physics is to continue to be as successful as it has been since Galileo in developing increasingly empirically successful and unifying theories, it is necessary that physicalism is true. Relative to the continuing existence of physics, construed in these terms, physicalism may be said to be *a priori.* On the other hand, we might require only that physics continues to make some progress, but does not make progress towards capturing a true unified theory of everything. Relative to this less demanding notion of physics, physicalism is not *a priori*, but a more or less disunified version of physicalism [disunified in ways (4) to (8)] is *a priori*.

VII

The history of western philosophy is split to its core by a long-standing, fundamental dispute. On the one hand there are the so-called empiricists, like Locke, Berkeley, Hume, Mill, Russell, the logical positivists, A. J. Ayer and Karl Popper, who hold empirical considerations alone can be appealed to in justifying, or providing a rationale for, claims to factual knowledge, there being no such thing as *a priori* knowledge – items of factual knowledge that are accepted on grounds other than the empirical. And on the other hand there are the so-called rationalists, like Descartes, Spinoza, Leibniz, Bradley, McTaggart, who hold that *a priori* knowledge does exist, and even plays a crucial role in science. Kant, famously, sought to resolve this debate by means of his claim that we do possess *a priori* knowledge of the world of appearance (since this must conform to the conditions required for it to be consciously experienced), but possess no knowledge whatsoever of the world of reality, the noumenal world of things in themselves. But Kant's attempted resolution of the debate fails. Perhaps our experiences must exhibit a certain degree of order, and cannot be completely chaotic, if these experiences are to be *conscious*, and are to be interpretable as experiences of a world distinct from the experiencing subject. If so, propositions ascribing such a degree of order to the world can never be refuted by experience because such refuting experiences would not be conscious. These propositions deserve to be regarded as being known *a priori*, their truth being a necessary requirement for there to be any conscious experiences at all. But any such propositions, *a priori* on Kantian grounds, fall far short, in content and specificity, of Kant's own candidates for *a priori* propositions (such as that space is Euclidian), and fall far short of what is required to be accepted on *a priori* grounds in order to make science possible. A highly aberrant world, in which objects abruptly and inexplicably disappear and appear, could easily be sufficiently orderly for conscious experience to be possible, but science as we know it would not be possible. Thus Kant fails to resolve the empiricist/rationalist dispute.

This long-standing dispute has been resolved, however, by the line of thought developed in this essay. The empiricists were right to deny the existence of *a priori* knowledge where this means factual knowledge of apodictic certainty justified independently of any appeal to experience. They were wrong, however, to deny the existence of *a priori* knowledge where this means *conjectural* items of factual knowledge whose acceptance is justified independently of any appeal to experience. Science requires there to be *a priori* knowledge in this latter sense, and two items of such knowledge have been exhibited: the level 7 thesis of partial knowability, and the level 6 thesis of meta-knowability.

In addition to resolving the empiricist/rationalist dispute, this essay has also developed a new conception of science – aim-oriented empiricism – and solved the long-standing problem of what it means to say of a theory that it is *unified* or *explanatory*. Furthermore, aim-oriented empiricism does not just change our *conception* of science; it requires that *science itself* needs to change. Science needs to become much more like the 17th century conception of natural philosophy, intermingling consideration of testable theories with consideration of untestable metaphysical, epistemological and methodological ideas. The whole relationship between *science* and *the philosophy of science* is transformed. The philosophy of science, construed as the exploration and critical assessment of rival ideas about what the aims and methods of science ought to be, ceases to be a meta-discipline, and becomes an integral part of science – or natural philosophy – itself. Rigour requires that, because of the inherently problematic character of the basic aim of science of improving knowledge about the universe *presupposed to be comprehensible*, even *physically comprehensible*, science and philosophy of science need to influence each other within the general framework of aim-oriented empiricism. There is, in addition, a major increase in the *scope* of scientific knowledge. The thesis that the universe is physically comprehensible (physicalism) ceases to be a mere metaphysical speculation, and becomes a central, firmly established tenet of (conjectural) theoretical scientific knowledge, more firmly established, indeed, than any physical theory, however empirically successful, such as quantum theory, general relativity, or the so-called standard model (the current quantum field theory of fundamental particles and forces).

Elsewhere I have shown that the line of thought developed in this essay is the first step in an argument, of much greater importance and scope, which demonstrates that there is an urgent need to change, not just science, but the whole of academic inquiry. In order to create a kind of inquiry rationally designed to help humanity learn how to make progress towards a better world, the aims and methods of academic inquiry need to be changed so that the basic aim becomes to promote wisdom by intellectual and educational means, wisdom being the capacity to realize what is of value in life for oneself and others, wisdom thus including knowledge, technological know-how and understanding, but much else besides. This broader argument for an intellectual revolution was first set out in Maxwell (1976b), and was given its definitive formulation in Maxwell (1984). The argument has been brought up to date in Maxwell (2004a). For summaries of the argument see Maxwell (2001, ch. 9 – a slightly improved version of Maxwell 2000), and

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Notes

1. This generalizes Einstein's remark, which was restricted to *mathematical* propositions: see (Einstein, 1973, 233).
2. Some years after my 1968 paper refuting Hume on causation, Armstrong and Tooley put forward anti-Humean accounts of laws and causation, taking no account of my earlier work: see Armstrong (1988) and Tooley (1977, 1987). Armstrong and Tooley have been, in my view, decisively criticized by van Fraassen (1989, Part I). Van Fraassen fails to take into account my earlier, 1968 refutation of Hume, and his criticisms of Armstrong and Tooley are not applicable to my account.
3. All the possible phenomena, predicted by any dynamical physical theory, T, may be represented by an imaginary "space", S, each point in S corresponding to a particular phenomenon, a particular kind of physical system evolving in time in the way predicted by T. In order to specify severely disunified rivals to T that fit all available evidence just as well as T does, all we need do is specify a region in S that consists of phenomena that have not been observed, and then replace the phenomena predicted by T with anything we care to think of. Given any T, there will always be infinitely many such disunified rivals to T. This point is inherent in Nelson Goodman's "new paradox of induction" (see Goodman, 1954), although the kind of empirically

successful disunified rivals considered by Goodman in his discussion of "grue" and "bleen" are but one kind of a number of kinds of disunified theories, as we shall see in section 3. There is a vast philosophical literature on the underdetermination of theory by evidence: for an excellent recent discussion, and reference to further literature, see Howson (2000): see especially ch. 1, 30-4, 75-7, and ch. 5. See also Lipton (2004).

4. For a more detailed discussion of empirically successful *ad hoc* rivals to accepted theories, see Maxwell: (1974; 1993; 1998, 51-4).

5. It may be objected that the universe might have been genuinely disunified, so that physics could consist only of a great number of physical laws. In this case, it may be argued, physics could not be construed as making a metaphysical assumption about underlying unity. But even in this counterfactual situation, endlessly many very much more disunified but empirically more successful rival laws could easily be formulated: these would have to be rejected on non-empirical grounds, or physics would drown in an ocean of rival laws. The persistent rejection of such much more disunified but empirically more successful rivals would involve the methods of physics making an implicit metaphysical assumption, to the effect that nature is unified to some extent at least (all grossly disunified laws being false). It is necessary to make some such assumption, however disunified the totality of accepted laws may be – even if the assumption made is rather weak in character, in that only gross disunity is denied.

6. For a criticism of the attempts of Popper (1959, ch. VII; 1963, p. 241), Friedman (1974), Kitcher (1981, 1989) and Watkins (1984, 203-13), see Maxwell (1998, 60-8). For criticisms of these and other attempts, see Salmon (1989). More recent, unsuccessful attempts at solving the problem are: McAllister (1996), Weber (1999), Schurz (1999), and Bartelborth (2002). For criticism of McAllister, see Maxwell (2004b, 2004c); for criticism of Weber, Schurz and Bartelborth see Maxwell (2004b)

7. The solution to the problem of unity of theory – the problem of what it means to say of a theory that it is explanatory – outlined here, summarizes a more detailed account to be found in Maxwell (1998, chs. 3 and 4). See also Maxwell (2004a, Appendix, section (2); 2004b; and 2004d).

8. An informal sketch of these matters is given in Maxwell (1998, ch. 4, sections 11 to 13, and the appendix). For rather more detailed accounts of the locally gauge invariant structure of quantum field theories see: Moriyasu (1983), Aitchison and Hey (1982: part III), and Griffiths (1987, ch. 11). For introductory accounts of group theory as it arises in physics see Isham (1989) or Jones (1990).

9. For accounts of spontaneous symmetry breaking see Moriyasu (1983) or Mandl and Shaw (1984).

10. The account of theoretical unity given here simplifies the account given in Maxwell (1998, chs. 3 and 4), where unity is explicated as "exemplifying physicalism", where physicalism is a metaphysical thesis asserting that the universe has some kind of unified dynamic structure. Explicating unity in that way invites the charge of circularity, a charge that is not actually valid: see Maxwell (1998, 118-23 and 168-72). The account given in this paper forestalls this charge from the outset. See also Maxwell (2004a, Appendix, Section 2).

11. It may be doubted that it is possible to distinguish unambiguously between theories that do, and theories that do not postulate *the same* dynamical laws throughout the range of phenomena to which the theory applies. Such doubts may stem from Goodman's arguments concerning "grue" and "bleen" (see Goodman, 1954), and from other considerations. For a rebuttal of these doubts and arguments see Maxwell (1998, ch. 4; 2004a, appendix, section 2).

12. If dark matter and quintessence exist and cannot be accounted for by the standard model and general relativity, then a specification of these phenomena would need to be added to the current disunified "theory of everything". Dark matter is postulated to account for the anomalous

rotation of galaxies, which rotate at a rate which would pull them apart unless invisible, unknown extra matter exists – so-called dark matter. Quintessence is a form of energy postulated to be inherent in space which has been postulated to account for the increase in expansion of the universe.

13. Physicalism(M,N), for any relevant value of M and N, is a *metaphysical* thesis because it is too imprecise to be empirically falsifiable (and it is not verifiable either).

14. It cannot even be argued that physics can be regarded as accepting "the true theory of everything is *at least* as unified as current fundamental physical theory" which, once accepted, may be added to, but will not be subsequently rejected, and may therefore be regarded as *a priori*. This thesis, for all we can know, may be rejected in the future, in that physicists find that progress in predictive power of theory requires an *increase* in the disunity of accepted fundamental physical theory. Perhaps the increase in theoretical unity in physics that we have witnessed since Galileo has been a lucky streak which will not continue into the future. Whether this is the case or not is an empirical matter, and therefore, on the face of it, not something that can be decided *a priori*.

15. For further discussion see (Maxwell 1998, 80-9, 131-40, 257-65 and additional works referred to therein).

16. I first expounded and defended a version of this hierarchical view in Maxwell (1974). It was further elaborated in Maxwell (1976b, 1984 and 1993). A more elaborate version still is expounded and defended in great detail in Maxwell (1998). For a more detailed defence of the version indicated here, see Maxwell (2004a, chs. 1 and 2, and appendix). In Maxwell (2005) I argue that this view is a sort of synthesis of the views of Popper, Kuhn and Lakatos, but an improvement over the views of all three.

17. Elsewhere I have argued in some detail that AOE succeeds in solving the problem of induction, insofar as it can be solved: see Maxwell (Maxwell 1998, ch. 5; 2004a, appendix, section 6; and especially 1984, 2nd ed., 2007, ch. 14).

18. The more insubstantial the thesis is, other things being equal, the easier it becomes to provide an *a priori* justification for its acceptance.

19. See Maxwell (1998, 169-71) for a list of twenty metaphysical theses which either fail to imply, or are incompatible with, the thesis of comprehensibility.

20. Prediction might be possible in the case of type (2) aberrance, as long as the conditions for an aberrant phenomenon to occur are not so complex and precise that it is impossible to reproduce them.

21. This requires that the true theory of everything remains true when interpreted essentialistically, as specifying necessitating properties possessed by the fundamental physical entity (or entities) postulated by the theory. The laws of the theory are true analytically, and the empirical import of the theory is bound up with the assertion of the theory: the world is made up of such and such physical entities possessing the necessitating properties specified by the theory.

22. For an earlier attempt at justifying acceptance of meta-knowability see Maxwell (1998, 186-93).