Does Physics Answer Metaphysical Questions?[1]

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1. Introduction

According to logical positivism, so the story goes, metaphysical questions are meaningless, since they do not admit of empirical confirmation or refutation. However, the logical positivists did not in fact reject as meaningless all questions about for example, the structure of space and time. Rather, key figures such as Reichenbach and Schlick believed that scientific theories often presupposed a conceptual framework that was not itself empirically testable, but which was required for the theory as a whole to be empirically testable. For example, the theory of Special Relativity relies upon the simultaneity convention introduced by Einstein that assumes that the one-way speed of light is the same in all directions of space. Hence, the logical positivists accepted an a priori component to physical theories. However, they denied that this a priori component is necessarily true. Whereas for Kant, metaphysics is the a priori science of the necessary structure of rational thought about reality (rather than about things in themselves), the logical positivists were forced by the history of science to accept that the a priori structure of theories could change. Hence, they defended a notion of what Michael Friedman (1999) calls the 'relativised' or the 'constitutive' a priori. Carnap and Reichenbach held that such an a priori framework was conventional, whereas Schlick seems to have been more of a realist and held that the overall relative simplicity of different theories could count as evidence for their truth, notwithstanding the fact that some parts of them are not directly testable. All this is part of the story of how the verification principle came to be abandoned, and how logical positivism transmuted into logical empiricism.

[1] This text is more or less that of a talk of the same title given to the *Royal Institute of Philosophy* on 10th February 2006. The relationship between science and metaphysics is discussed in more detail in Ladyman and Ross (2007).

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Yet there is no doubt that the crude view that the positivists banished metaphysics altogether was considerably influential despite the more nuanced history that is now being told. For example, here is John Watkins in 1975:

> The counter-revolution against the logical empiricist philosophy of science seems to have triumphed: I have the impression that it is now almost as widely agreed that metaphysical ideas are important in science as it is that mathematics is. (91)

Watkins celebrates the work of historians of science who showed 'the decisive role that certain metaphysical speculations have played in the advancement of science' (91). Since he wrote it has become ever more widely acknowledged that metaphysical questions are meaningful and important, and metaphysics is now enjoying something of a renaissance. In philosophy of science, the acceptance of metaphysics is due in part to the emergence and dominance of scientific realism. For one definition of metaphysics is that it is the study of the nature of reality beyond the appearances of things, and scientific realism is the position that we ought to believe in the unobservable entities, such as atomic and subatomic particles, fields, and black holes, postulated by our best scientific theories. Unobservable entities are now fundamental to a great deal of science and especially physics, and the theories that describe these unobservable entities clearly purport to describe reality beyond the appearances. Therefore, that metaphysical questions can be answered by physics seems to follow from scientific realism.[2] This is surely a significant general consideration (of which more below), but perhaps a more important part of the explanation of the seriousness with which philosophers of science now take metaphysics is the fact that a number of fundamental metaphysical doctrines are widely perceived to be important parts of the content of physical theories. For example, Special Relativity is thought to imply that all times are real, and quantum mechanics is thought to imply indeterminism. (More of these specific cases below.)

However, other factors have led to metaphysics being regarded as not merely a meaningful and legitimate part of philosophy, but also as an autonomous and non-empirical science. One of these is that philosophers of science began to turn to metaphysics in an attempt

[2] Indeed a recent textbook (Couvalis, 1997) on philosophy of science defines scientific realism as the view that metaphysical questions can be answered by science.

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to explain the continuity of reference between successive scientific theories that gave competing descriptions of unobservable entities. The causal theory of reference, and ideas such as rigid designation, were in part a response to the challenge to scientific realism raised by the historicism of Kuhn and others. Hence, it began to look as if scientific realism needed to be grounded in metaphysics. Furthermore, there was a general acceptance in analytic philosophy after the heyday of Quineanism that modality could not be eliminated either from philosophy or from the rational reconstruction of science, and so the metaphysics of possible worlds, causation, and laws became central areas of philosophical concern. The philosophers pursuing these issues did not detect any prospect of science being able to settle them, and so nowadays metaphysics is pursued by many who regard it as sovereign.

2. Autonomous versus Naturalised Metaphysics

It is a commonplace among contemporary philosophers that the systematic divide among the great early modern philosophers into rationalists and empiricists is an artefact of the histories of philosophy from the late nineteenth century that whiggishly construed rationalism and empiricism as thesis and antithesis prior to celebrating Kant's cunning synthesis. That said, there is no doubt that we can detect the binary opposition within contemporary philosophy, and as ever no where is it more evident than within metaphysics. Representing the resurgent voice of the analytic metaphysicians here is Jonathan Lowe:

> ... metaphysics goes deeper than any merely empirical science, even physics, because it provides the very framework within which such sciences are conceived and related to one another (2002, vi)

According to him the universally applicable concepts that metaphysics studies include those of identity, necessity, causation, space and time. Metaphysics must say what these concepts are and then address fundamental questions involving them, such as whether causes can have earlier effects. Metaphysics other main job according to Lowe, is to systematise the relations among fundamental metaphysical categories such as things, events, properties, and so on. Leaving aside the latter, we might reasonably

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ask how metaphysical enquiry ought to proceed and Lowe adopts the familiar methodology of reflecting on our concepts (conceptual analysis).

Frank Jackson (1998) has also recently defended the idea of metaphysics as conceptual analysis. The problem these philosophers have is with explaining why we should think that the products of their activity reveal anything about the deep structure of reality rather than merely telling us about how we think about and categorise reality. Even those fully committed to a conception of metaphysics as the discovery of synthetic a priori truths shy away from invoking a special faculty of rational intuition that delivers such knowledge; rather they usually just get on with their metaphysical projects and leave the matter of explaining the epistemology of metaphysics for another occasion. Ted Sider defends this strategy by pointing out that lack of an epistemological foundation for science and mathematics does not prevent practitioners from getting on with the business of advancing the state of knowledge in these domains (2001, xv). The obvious rejoinder to this, which he does not consider, is that we know a tree by its fruits and mathematics and science have undoubtedly borne fruits of great value; pure metaphysics has not achieved anything comparable, if it has achieved anything at all.

Furthermore, naturalists have good positive reasons to be sceptical about a priori metaphysics. There is no reason to believe that human beings naturally endowed cognitive capacities extend to the provision of reliable information about the fundamental structure of reality.[3] So the only kind of metaphysical enquiry that ought to be taken seriously, if any, is naturalised metaphysics. (Of course the naturalist concedes that if a metaphysical system is internally consistent then it can be rejected a priori.)

Lowe has two arguments against this:

(i) '... to the extent that a wholly naturalistic and evolutionary conception of human beings seems to threaten the very possibility of metaphysical knowledge, it equally threatens the very possibility of *scientific* knowledge ...' (6) Since natural selection cannot explain how natural scientific knowledge is possible so the fact that it cannot explain how metaphysical knowledge is possible gives us no reason to suppose that such knowledge is not possible.

(ii) Naturalism depends upon metaphysical assumptions.

[3] For more on this see Ladyman and Ross (2007), 1.1 and 1.2.

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In response though note that even if it is granted that natural selection cannot explain how natural scientific knowledge is possible, we have plenty of good reasons for thinking that we do have such knowledge. On the other hand, we have no good reasons for thinking that metaphysical knowledge is possible. (Recall the point against Sider above.) It seems that their predilection for a priori argument leads metaphysicians to discuss the status of metaphysics compared to science a priori as if we didn't know a posteriori that the track record of science gives us reason to take it epistemically seriously that we lack in the case of metaphysics. With respect to Lowe's second argument here, it is enough to point out that even if naturalism depends on metaphysical assumptions, the naturalist will argue that the metaphysical assumptions in question are vindicated by the success of science, by contrast with the metaphysical assumptions on which autonomous metaphysics is based which are not vindicated by the success of metaphysics since it can claim no such success.

According to Lowe, it is the job of metaphysics to tell us what is possible, but it may be conceded that which of the possible fundamental structures of reality exists can be answered only with empirical evidence. The problem with this is that philosophers have often regarded as impossible states of affairs that science has come to entertain. For example, metaphysicians confidently pronounced that non-Euclidean geometry is impossible, that it is impossible that there not be deterministic causation, that non-absolute time is impossible, and so on. Furthermore, there is no agreement now among metaphysicians about what is metaphysically possible. For example, some metaphysicians believe that infinitely divisible matter is possible and others that it is not.

In any case, suppose that naturalised metaphysics is the only option. It remains an open question whether it is possible to learn metaphysical lessons from science. Since metaphysics does not give rise to empirical predictions it cannot be directly confirmed by a physical theory. However, metaphysical theories can be incompatible with physical theories, and hence the former can be ruled out or at least undermined by the confirmation and adoption of the latter. For example, Cartesian metaphysics is incompatible with Newtonian physics because the former has it that space is filled with a plenum and that all action is action by contact, whereas the latter involves particles moving in a void subject to the force of gravity that seems to act at a distance. For Watkins, metaphysics is part of the hard core of a Lakatosian research programme. It cannot be directly refuted but if the research programme persistently

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degenerates then the hard core must eventually be abandoned. Arguably this happened to Aristotelian and Cartesian metaphysics, and then later it happened to the metaphysical framework of classical physics in the face of relativity and quantum physics. As Sider says in a more naturalistic mood: '... in cases of science versus metaphysics, historically the smart money has been on science ...' (2002, 42). (Sider seems to think that metaphysical knowledge can be a priori but that metaphysics is also required to be compatible with current science.)

Let us grant then that the failure of a metaphysical framework to help in the production of good science can count as a reason against it. Is it also plausible that the success of science based on a particular metaphysical framework provides some evidence for the latter? For example, the success of materialism as a research programme in science in the seventeenth and eighteenth centuries was arguably evidence for it. (Of course, the conception of matter integral to materialism, namely that of extended substance, became untenable in the nineteenth and twentieth centuries.)

Katherine Hawley (2006) helpful distinguishes a number of possible positions one might take on the relationship between metaphysics and science. Hawley assumes that it is sometimes at least possible to provide reasons for and against metaphysical claims and that science is not the only source of such reasons; she therefore thinks that 'metaphysical enquiry can be reasonable even where it outruns the scope of science' (454). Purely a priori reasons for metaphysical claims may involve appeals to intuition, explanatory power, simplicity, or perhaps the results of conceptual analysis. As was mentioned above, naturalists will be suspicious of appeals to intuitions not least because intuitions vary so much, and also because even were we agreed in our intuitions, they doubt that there is any reason to believe that our intuitions track the truth about metaphysical matters any more than they do about motion, gravity or the constitution of material objects. When it comes to explanatory power, naturalists must agree that inference to the best explanation is indispensable in science and so the question can only be whether there is any difference between metaphysics and science in respect of explanation. There is an important such difference, namely that what metaphysical hypotheses are supposed to explain are often metaphysician's intuitions or 'common-sense beliefs'. In the light of this, naturalists ought to be very sceptical about the extension of the methodology of inference to the best explanation

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into metaphysics, and about the worth of pursuing metaphysical enquiry where it goes beyond the scope of scientific enquiry.[4]

However, we can at least agree with Hawley that an outright sceptic about inference to the best explanation like Bas van Frasssen must eschew metaphysics, just as he does scientific realism. Hence, some form of realism about science is a necessary condition for believing that in principle science can answer metaphysical questions. According to Hawley, 'optimism' is the view that 'the involvement of a metaphysical claim in an empirically successful scientific theory provides some reason to think that the claim is true' (456). This idea that in principle science can answer metaphysical questions is the negation of Hawley's 'Radical Pessimism'. She thinks that scientific realism is sufficient for optimism because there is no 'in-principle difference between claims about unobservable 'scientific' entities and 'metaphysical' claims' (459). The idea is that since the theoretical claims of science concerning unobservable entities go beyond the empirical content of the relevant theories, the scientific realist is committed to the idea that the empirical success of theories gives us reason to believe their theoretical content. The onus is on the sceptic about metaphysics to point out some relevant semantic or epistemic difference between the theoretical content and the metaphysical content of theories and there is good reason to think this cannot be done. One of way of thinking about this is in terms of the Quinean notion of the web of belief. Metaphysical hypotheses are as much part of the web as theoretical scientific hypotheses, and since neither can be confirmed or refuted in isolation, in principle they have the same epistemic status.

Let us grant all this for the moment. It follows that the scientific realist must deny radical pessimism and so they must chose between the following two positions:

(1) Metaphysical claims have in fact been established by science.
(2) Although in principle metaphysical claims might be established by science, in fact they have not been.

(Hawley talks not of science establishing metaphysical claims but of it providing some reason to think they are true. However, this is too weak: The sceptic about metaphysics may concede that science gives us some reason to believe a particular metaphysical claim, but deny that the reasons in question are anywhere near compelling.)

[4] Again see Ladyman and Ross (2007), 1.1 and 1.2 and also van Fraassen (2002), chapter 1.

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If it is supposed that scientific realism implies that metaphysical hypotheses have been established by science, and it turns out that metaphysical hypotheses have not in fact been established by science, then by modus tollens, scientific realism must be false. Hence, close attention to the role of metaphysics in physics and to the fate of metaphysical hypotheses in the history of physics may bolster scepticism, not just about metaphysical knowledge, but also about scientific realism. On the other hand, if it is supposed that scientific realism only requires that metaphysical hypotheses can in principle be established by science, but they have not in fact been, then it may be objected that the form of scientific realism that results is too attenuated to really be worth the name. After all, as Hawley says, there is no clear demarcation between a theoretical claim and a metaphysical one, and indeed claims about unobservable entities become empty if nothing is said about their metaphysical status. For example, the claim that light is transmitted as waves in the ether is empty without some account of what the ether is supposed to be.[5]

3. Metaphysical questions that might be thought to be answerable by physics:

Here are some examples:

(i) Are all times real?
(ii) Does time flow?
(iii) Is there a global asymmetry in time in the universe?
(iv) Is time travel possible?
(v) Is the world deterministic[6]?
(vi) Can a cause succeed its effect in time?
(vii) Is there action at a distance or does all causation happen locally in space and time?
(viii) Is the identity of indiscernibles true?
(ix) Do space (and/or time) exist independently of their material contents?
(x) Are space and time discrete or continuous?
(xi) What is the geometry of space(time)?

[5] For more on the status of the metaphysical content of theoretical claims see Ladyman and Ross (2007), 2.2.

[6] Determinism is here understood as a modal thesis: given the state of the world at some time, there is only one way it *could* be at any later (or earlier) time.

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(xii) How many dimensions are there to spacetime
(xiii) What is the topology of space(time)?
(xiv) Is the universe finite or infinite?
(xv) Are there parallel universes?

4. The Philosophy of Time

Questions (i) to (iv) all concern time. They are related but nonetheless distinct although often conflated. In relation to (i), call the view that all events are real 'eternalism', the view that only the present is real 'presentism', and the view that all past and present events are real 'cumulative presentism.' (The latter is defended by Michael Tooley (2000) although not under this name). (ii) is often expressed in terms of whether there is temporal passage or objective becoming. Those who believe in the passage of time or objective becoming often also believe that the process of becoming is that of events coming into existence and going out of existence, but this need not be so; to suppose there is becoming, one need only believe that there is some objective feature of the universe associated with the passage of time. Objective becoming could be like a light shining on events as they are briefly 'present', and is therefore compatible with eternalism.[7] On the other hand, both presentism and cumulative presentism entail a positive answer to question (ii), since if events do come into existence, whether or not they then stay existent or pass out of existence, this is enough to constitute objective becoming. Since McTaggart's famous argument for the unreality of time, metaphysicians have often discussed (i) and (ii) in the context of a question in the philosophy of language namely: Is tensed language reducible to tenseless language, or does tensed language have tenseless truth conditions? (*) However, the philosophy of language cannot settle the metaphysical issues as Michael Tooley (2000) argues. So even though the standard opposition is between those who answer 'no' to (i), 'yes' to (ii), and 'no' to (*) on the one hand (the defenders of McTaggart's 'A-series'), and those who answer 'yes' to (i), 'no' to (ii), and 'yes' to (*) (the defenders of McTaggart's 'B-series'), a variety of more nuanced positions are possible. (Note that it is not clear on reflection that the negation of presentism is a necessary condition for the possibility of time travel.)

[7] Tim Maudlin (2002) argues that the passage of time may be an objective feature of the universe even if eternalism is true.

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In relation to (iv), clearly if (i) or (ii) are answered positively then that is enough to privilege a particular direction in time. However, eternalism and the denial of objective becoming are compatible with time having a privileged direction, since there could be some feature of the block universe that has a gradient that always points in some particular temporal direction. For example, the entropy of isolated subsystems of the universe, or the universe itself, might always increase in some direction of time. Another well known possible source of temporal direction was proposed by Reichenbach (1956) who argued that temporal asymmetry is grounded in causal asymmetry: in general, correlations between the joint effects of a common cause are screened off by the latter but the joint causes of a common effect are uncorrelated. Although some have claimed that Reichenbach's Principle of the Common Cause is violated, not least by the behaviour of entangled states in quantum mechanics (see for example van Fraassen 1991), such considerations are sufficient to show that conceptually the question of the direction of time must be separated from questions about eternalism. However, it may be that no physical meaning can be attached to the idea of the direction of time in the whole universe, because no global time co-ordinate for the whole universe can be defined. This seems to be implied by special relativity.

The status of time in special relativity (SR) differs from its status in Newtonian mechanics in that there is no objective global distinction between the dimensions of space and that of time. Spacetime can be split into space and time, but any such foliation is only valid relative to a particular inertial frame, which is associated with the Euclidean space and absolute time of the co-ordinate system of an observer. This seems to imply eternalism, since if there is no privileged foliation of spacetime, then there is no global present, and so the claim that future events are not real does not refer to a unique set of events.[8] Furthermore, many have argued that, since SR implies the relativity of simultaneity, whether or not two events are simultaneous is a frame-dependent fact, and therefore there is no such thing as becoming.[9] However, this is too quick. It is possible to advocate a form of becoming that is relative

[8] Of course, one could argue that the very notion of reality must be relativised to observers, but this is to give up on the kind of metaphysics at issue.

[9] The literature on these topics is voluminous but among the most influential papers are Gödel (1949), Putnam (1967), and Stein (1968) and (1989).

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to observers or events, so strictly speaking it is only absolute becoming that is ruled out by the lack of absolute time in special relativity. Since the light cone structure of Minkowski spacetime is Lorentz invariant, it can be regarded as absolute. It is easy then to define a notion of the open future of an event E, since any event E' in the forward lightcone of E will have events in its backwards lightcone that are not in the backwards lightcone of E, meaning that there is a sense in which it can be claimed that E' is not determinate at E. This notion of becoming is objective in the sense that all observers will agree about which events are in the open future of a given observer at a particular point in his or her history, because all observers agree about the light cone structure of spacetime.[10]

In any case there is a fundamental problem with drawing metaphysical conclusions about the nature of time from special relativity, namely that it is a partial physical theory that cannot describe the whole universe.[11] For that we must turn, in the first instance, to general relativity (GR), and the implications of that theory for time are not clear. This is because GR gives us field equations that are compatible with a variety of models having different global topological features, and different topological structures may have very different implications for the metaphysics of time. For example, if the topology of the universe is globally hyperbolic then it is possible to define a single global foliation of spacetime for it; otherwise it may not be. Clearly we must then turn to cosmological models of the actual universe, of which there are many compatible with the observational data. As yet there is no agreement about which of these is the true one. Highly controversial issues about the cosmological constant and so-called

[10] Another possibility is to argue that while Special Relativity is empirically adequate, the empirical evidence is nonetheless compatible with the existence of a privileged foliation. This would be to advocate along the lines of that originally proposed by Lorentz and Fitzgerald. This is the strategy adopted by Tooley (2000) for example. Naturalism forbids the revision of scientific theories on purely philosophical grounds, so the proposal of a privileged foliation contra to SR requires a scientific motivation. One possible scientific motivation is the adoption of a solution to the measurement problem that posits a preferred frame of reference. Another is the identification of foundational problems with the account of relativistic phenomena in the Minkowski spacetime framework (see Bell 1987 and Brown 2005).

[11] Syder (2001) is a recent example of a metaphysician who confines discussion to the implications of Special Relativity.

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dark energy, dark matter, and the nature of singularities, as well as the various approaches to the search for a theory of quantum gravity, all bear on the question of whether spacetime will turn out to admit of a global foliation, and hence on whether absolute time is physically definable. Even if it does turn out to be definable, there remains the question of whether such a definition ought to be attributed any metaphysical importance. For example, it is possible to define something called 'cosmic time' which is based on the average properties of the universe's global matter distribution under the expansion of the universe. Some have argued that we can regard Cosmic Time as giving us a privileged foliation (Lucas and Hodgson, 1990). However, others argue that the fact that such a foliation can be defined gives us no reason to regard it as having an objective significance (Berry, 1989), not least because it is based on averages that have nothing to do with the phenomenological experience of everyday simultaneity for objects whose states of motion are not the same as the state of motion of the galaxies in our region of the universe with respect to which cosmic time is defined (see Bourne, 2004).

Non-relativistic many-particle quantum mechanics does not directly bear on the philosophy of time since the status of time in the formalism is not novel in the same way as in relativity. However, it has often been argued that quantum physics is relevant to questions about the openness of the future, becoming, and the direction of time, because of the alleged process of collapse of the wavefunction. Since Heisenberg (1962) it has been popular to claim that the modulus squared of the quantum mechanical amplitudes that are attached to different eigenstates in a superposition represent the probabilities of genuinely chancy outcomes, and that when a measurement is made there is an irreversible transition from potentiality to actuality in which the information about the weights of the unactualised possible outcomes is lost forever. Hence, measurement can be seen as constituting irreversible processes of becoming that induce temporal asymmetry. However, quantum measurements need not be so understood not least because some deny that collapse is a genuine physical process and also because realism about the wavefunction is highly contentious. Similarly, if there is no collapse, as in the Everett interpretation, then again there is no temporal asymmetry in quantum mechanics.

The upshot seems to be that the status of the arrow of time in quantum mechanics is open.

There is also a vast literature about whether or not the second law of thermodynamics represents a deep temporal asymmetry in

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nature. The entropy of an isolated system always increases in time, and so this seems to be an example of the arrow of time being introduced into physics. If the whole universe is regarded as an isolated object, and if it obeys the second law, then it would seem that there is an objective arrow of time in cosmology. However, it is not clear what the status of the second law is with respect to *fundamental* physics. One possibility is that the second law holds only locally, and that there are other regions of spacetime where entropy is almost always at or very near its maximum. (Boltzman himself thought this was the case in his later years.) Even if thermodynamics seems to support the arrow of time, it is deeply puzzling how this can be compatible with an underlying physics that is time asymmetric. Conservative solutions to this problem ground the asymmetry of the second law in boundary conditions rather than in any revision of the fundamental dynamics. The most popular response is to claim that the law does indeed hold globally but that its so doing is a consequence of underlying time-reversal invariant laws acting on an initial state of the universe that has very low entropy. This is called the 'Past Hypothesis' by Albert (2000). A much more radical possibility is that the second law is a consequence of the fact there is a fundamental asymmetry in time built into the dynamical laws of fundamental physics. Given the outstanding measurement problem in quantum mechanics those who propose radical answers to problems in thermodynamics and cosmology often speculate about links between them and the right way of understanding collapse of the wavefunction. Both the question of eternalism, and the arrow of time, lead inexorably to cosmology and thence to the realm of quantum gravity.

5. Quantum Gravity[12]

A theory of quantum gravity must do all of the following: say what happens in nature at the Planck length (10^{-33}cm); recover GR as a low-energy limit; and provide a background spacetime, at least phenomenologically, for conventional quantum theories. What else it should do is a matter of great contention. Some, such as advocates of string theory and M-theory like Brian Greene (2004), think it must also unify the four fundamental forces of nature;

[12] Introductions to the philosophy of quantum gravity include Callender and Huggett (2001) especially the introduction, and Rovelli (2004), chapter 1. Wallace (2000) is also very helpful.

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others, such as Smolin (forthcoming), argue that, in the first instance at least, it need only amount to a quantised version of GR. A further question is whether quantum gravity must also be a cosmological theory of one (unique and actual) universe, rather than allowing for models representing a variety of universes.

Quantum gravity must reconcile a number of profound tensions between GR and quantum theories. Most obviously, quantum physics is the physics that best describes the phenomena when we look at very short length scales, and GR is physics that was specifically designed with a distinction between local and global properties of spacetime in mind, and sought to describe deviations from the topological, geometrical and metrical properties of Minkowski spacetime that only show up in large scale structure—this is the scale tension. Secondly, GR depends on the identification of inertial and gravitational mass, and the equivalence between accelerating and gravitational frames, whereas quantum theory was originally developed to account for the interaction between electro-magnetic radiation and matter. Initially, it was only the energy states of matter that were quantised, but subsequently it has proved possible, with differing degrees of success, to quantise all the fundamental forces, with the exception of gravity—this is the force tension. Thirdly, relativistic theories obey the condition that there are invariant, and hence objective causal pasts for events, whereas in QM there are nonlocal correlations that some regard as evidence of action at a distance—this is the causal tension. Finally, there is the radically different status of time in quantum theory versus GR. In the former, time is a parameter external to all physical systems; in the latter it is a co-ordinate with no particular physical significance. More specifically there is something called 'The Problem of Time' the upshot of which is that theories of quantum gravity are in danger of saying there can be no change in the universe over time (I return to this below).

Depending on who one listens to, string theory has either already led us a considerable distance down the road to a complete theory of quantum gravity, or it has achieved absolutely nothing that counts as physics rather than mathematics. String theorists have followed the methodology that was used in the construction of quantum field theories, namely the search for fundamental symmetries. If the string theory vision is correct then the ultimate fundamental physics will describe the universal symmetries of the universe. (Another important commonality between string theory

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and classical and quantum physics is that they posit a continuous space and time, which is departed from by some rival programmes—see below.)

Lee Smolin is highly critical of string theory and argues that it is not falsifiable in the sense that it makes no 'falsifiable predictions for doable experiments' (2006, 197). He claims there are no fundamental global symmetries, on grounds that those theories that posit them are not fully empirically adequate. His view is that the two big ideas that drive string theory, namely unification and symmetry, have run their course, and that there have been no substantially new results in particle physics since 1975. He points out that the standard model has so many adjustable parameters that any likely experimental data from particle accelerators can be accommodated by it.[13] He also emphasises that there are at least 10^{100} possible string theories, and argues that all the ones that have been studied disagree with the data. Super-symmetric string theory has 105 free parameters. Hence, Smolin claims, partisans will be able to maintain that whatever comes out of the next generation of particle accelerators confirms super-symmetry.

He also criticises string theory for being 'background dependent' in the sense that it relies on a background spacetime structure. Smolin predicts that the correct theory of quantum gravity will be relational in the sense that it won't posit any background structure which does not change with time but which is necessary for the definition of kinematical quantities and dynamical laws (ibid.). Newtonian mechanics, SR, quantum theories including quantum field theories, and string theory are all background-dependent and rely on various structures that are outside the scope of the dynamics of the theory. For example, in ordinary quantum mechanics the spacetime and the algebraic structure of Hilbert space are part of the background structure. On the other hand, GR, understood as a cosmological theory of the whole universe, is a relational theory in the sense that the physically important structural features of the theory are dynamical. The only background structure in GR consists of the dimensionality, the differential structure, and the topology.

String theorists now seem to have accepted that background independence is a desideratum. Brian Greene speculates about a background free version of string theory, and the search for so-called M-theory is partly motivated by the need for a way of

[13] There are at least 19 free parameters in the standard model plus almost as many from cosmology.

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thinking about strings that does not treat them as vibrations in a background spacetime. However, no such theory yet exists. Meanwhile, Smolin has inspired a significant minority of researchers to seek background independence in other approaches to quantum gravity, and he shows how this notion plays out in the context of a variety of these theories. He suggests that the history of physics testifies to the success of the pursuit of background independence. It is true that progress has sometimes been made in physics by eliminating background structure. SR eliminated the background structure of absolute space and time, and then GR eliminated the background structure of Minkowski spacetime. On the other hand, there have been many background dependent theories that have been highly successful, including quantum theories. Smolin himself concedes that GR is background dependent in certain respects. Furthermore, consider the success of the pursuit of symmetry and unification of forces that motivates string theory, in generating the standard model and the unified field theories based on the knitting together of the symmetry groups previously discovered to be governing the separate forces. Smolin and Greene's dispute can be construed as concerning which of the following two desiderata for fundamental physics holds trumps: symmetry or background independence. The empirical evidence is equivocal, to say the least.

Among background independent approaches the most well-known is canonical quantum gravity. This approach seeks a quantum theory of gravity, but not necessarily a unification of all the fundamental forces. This gives rise to the famous Wheeler-DeWitt equation, and the infamous Problem of Time: the physical states of the universe must be time-independent, and so nothing changes. The latest version of the canonical programme is loop quantum gravity. The pioneers of this approach include Abhay Ashtekar, Carlo Rovelli, John Baez, and Lee Smolin. Other approaches include:

Causal set theory: This is a background independent approach motivated by the assumption that at the Planck scale spacetime geometry will be discrete, and by the fact that a discrete causal structure of events is almost sufficient to define a classical General Relativistic spacetime (see Malament 2006). The formalism models spacetime as a partially ordered set of primitive elements with a stochastic causal structure representing the probabilities for 'future' elements to be added to a given element. The 'volume' of spacetime is then recovered from the number of elements. The 'dynamical structure' is compatible with eternalism because the

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whole of spacetime can be considered as a single mathematical structure, and temporal relations regarded as just the order of elements. The probabilistic structure is required to be local. It can be shown that a classical spacetime can always be approximated by a causal set. However, the converse does not hold and this is a major problem for this approach (see Smolin 2006). Note that a causal set is a partially ordered set where the intersection of the past and future of any pair of events is finite: '[T]he fundamental events have no properties except their mutual causal relations.' (210).

Causal triangulation models: These models use a combinatorial structure of a large number of 4-simplexes (the 4-d version of a tetrahedron), from which a classical spacetime will emerge as a low energy limit, and from which quantum theory can be recovered if background assumptions are made. Interestingly, the latest simulations of spacetime emerging dynamically from these models generate it as four-dimensional on large scales, but two-dimensional at short distances (and it is known that a quantum theory of gravity is renormalisable in two dimensions).

Topological quantum field theories, twister theory, and non-commutative geometry: these approaches are highly abstract and speculative at present.

Another approach worth mentioning has the unique feature that the temporal dimension is abandoned altogether, namely Julian Barbour's relationism: Time is supervenient on change, but change is just differences between distinct instantaneous three dimensional spaces.

All of these research programmes use new and highly abstract mathematical structures to describe the universe, and theorists hope to get the familiar behaviour of spacetime and quantum particles to emerge as limiting behaviour. It seems clear that we cannot yet say what the metaphysical implications of quantum gravity are, but the possibilities range from eleven dimensions to two, from a continuous fundamental structure to a discrete one, and from a world with universal symmetries to one with none.

With respect to the metaphysics of time, it seems that it is an open question whether there is a objective global asymmetry in time, and whether such dynamical structure as there is in the universe reflects a fundamentally tensed reality or whether eternalism is true. (Mathematically, perhaps the real issue is between three—or more—plus one dimensions and four.) If M-theory is the correct theory of quantum gravity then there will be universal symmetries that are not time dependent, and they may define a background independent structure. If there is no

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background independent structure and asymmetry in time is part of fundamental physics, then it may be that there is 'dynamics all the way down' and reality is fundamentally tensed.

One possible motivation for the dynamical view is a principle that van Fraassen sometimes seems to endorse, namely that there is nothing that's both perfectly general about all of reality and also true. This coheres with the idea that there is dynamics all the way down in the universe, since any fundamental properties that hold generally would necessarily be time-independent and hence amount to background structure. Consider Smolin: 'The universe is made of processes, not things' (2001, 49). Smolin insists that a lesson of both relativity theory and quantum theory is that processes are prior to states. Classical physics seemed to imply the opposite because spacetime could be uniquely broken up into slices of space at a time (states). Relativity theory disrupts this account of spacetime and in QM nothing is ever really still it seems, since particles are always subject to a minimum amount of spreading in space and everything is flux in quantum field theory, within which even the vacuum is the scene of constant fluctuations.

However, one of the lessons of quantum gravity is that some philosophers—especially standard scientific realists—have jumped to overly strong metaphysical conclusions on the basis of not taking account of all the possibilities still held open by physics. There are two leading examples where what some philosophers treated as decisive rulings from physics are now questioned. One of these is the case we have just been discussing, namely, whether or not we live in a block universe. The other is the alleged discovery by quantum theory that the world is not deterministic. In Bohm theory and the Everett approach, the world comes out deterministic after all. Clearly, theories that seem to wear their metaphysical implications on their sleeves often turn out to admit of *physical* reconstruction in different terms. Many physicists have attempted to resolve tensions between QM and GR by seeking what can be regarded as the key metaphysical truth that lies behind each theory's empirical success. For example, Barbour and Smolin think that relationism is the basis for the success of relativity theory. Often it is argued that the truth of quantisation that lies behind the empirical success of QM means that theorists should pursue discrete structures of space and time as in the programmes of causal set theory. If each instant is ontologically discrete then why should the timeline be continuous? On the other hand, the key insight of QM might also be regarded as the superposition principle, and the consequent problem of entangled states.

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So it is not clear which aspects of the metaphysical foundations of contemporary physics—for example, continuous space and time, or four-dimensionalism—will be preserved in quantum gravity. Given the diversity of philosophical and foundational presuppositions and implications currently abroad—for example, ranging from a return to absolute time to nihilism about time, and from ten dimensional continuous spaces to discrete graphs—there is little positive by way of implications for metaphysics that we can adduce from cutting edge physics. However, when it comes to negative lessons, there is more to be said. None of the existing contenders for a theory of quantum gravity is consistent with the idea of the world as a spatio-temporal manifold with classical particles interacting locally. This is not surprising to anyone who has thought about the implications of Bell's theorem. It is important that this is not a theorem about quantum mechanics, but rather tells us something about any possible empirically adequate successor to quantum mechanics, namely that it cannot be both local and posit possessed values for all measurable observables. We are justified in treating as unmotivated the idea that any theory of quantum gravity will be a local realist theory, and we should restrict consideration in metaphysics to theories that are compatible with the violation of Humean supervenience implied by entanglement.

6. Scientific Realism and the Metaphysical Content of Physical Theories.

Here is Larry Sklar:

> ... it is a great mistake to read off a metaphysics superficially from the theory's overt appearance, and an even greater mistake to neglect the fact that metaphysical presuppositions have gone into the formulation of the theory in the first place. (Sklar 1981, 131)

Steven French is another philosopher of physics who has expressed scepticism about the attempt to learn metaphysical lessons from physics. French argues that it is not possible to read the answers to metaphysical questions off our best physics because there is an underdetermination of metaphysics by physics (1998).

It turns out that when we examine any of the instances of alleged metaphysical knowledge being delivered by scientific theories, there are always a number of extra assumptions needed to derive the conclusion which we can contest. So, for example, Einstein

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contested indeterminism in the face of quantum mechanics by denying that the latter is a complete description of reality. In general, there is the problem of scientific theories underdetermining metaphysics. In the case of quantum mechanics, for example, it is widely known following the work of John Bell that no local deterministic hidden variable theory can replace quantum mechanics and still be empirically adequate. However, a nonlocal hidden variables theory can do so, as is the case with Bohm theory. So we see that a metaphysical package may be ruled out or in, but not metaphysical assumptions taken singly.

It is worth remembering that scientific theories have issued metaphysical claims before, only for subsequent developments to have shown the theories in question to be erroneous in certain fundamental respects. So, for example, Fresnel's ether theory is now regarded as featuring a central theoretical term, 'ether', which does not refer to anything in the world. Given this the best we can say about our best theories is that they are approximately true. This may give cause for doubt that we ought to believe their metaphysical implications.

Recent realist responses to the arguments against scientific realism from theory change have separated the parts of theories that essentially contributed to their novel predictive success from the 'idle' parts of theories. The problem for our project of learning metaphysics from physics is that the idle parts often turn out to be the metaphysical parts. For example, Psillos (1996) argues that in the case of caloric theory all the important predictive successes of the theory were independent of the assumption that heat is a material substance, and in the case of the ether, the predictive success of Fresnel's wave theory of light were independent of the assumption that the ether is a material solid. The other problem with the historical record is that the pessimistic meta-induction becomes much stronger if we confine ourselves to considering the fate of metaphysical posits in the history of science rather than theoretical posits in general. Claims about the existence of unobservable entities may not often be renounced but claims about the metaphysical nature often are.

Other problems in reading off our metaphysics from our best science include the following:

(a) There is no fundamental unity in physics since quantum mechanics and general relativity have not so far been conjoined consistently. This might suggest that we should

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suspend judgement about the metaphysical implications of both theories until we see which are carried over to their successor.

(b) The measurement problem in quantum mechanics means that we lack a consistent interpretation of the theory that is agreed upon by most physicists.

(c) Scientific theories often come in multiple formulations which may suggest different metaphysical pictures, and theories are only applied to the world via models. So we might doubt whether the empirical success of science ought to make us believe that a particular fundamental theory is true.

(d) Metaphysical component of scientific theories makes the problem of defining approximate truth come to the fore.

The topic of this paper was addressed by Sir James Jeans in 1942 in his book *Physics and Philosophy*. Towards the end comes this passage:

> There is a temptation to try to round off our discussion by summarizing the conclusions we have reached. But the plain fact is that there are no conclusions. If we must state a conclusion, it would be that many of the former conclusions of nineteenth-century science on philosophical questions are once again in the melting pot. (216)

He continues:

> ... physics and philosophy are at most a few thousand years old, but probably have lives of thousands of millions of years stretching away in front of them. They are only just beginning to get under way, and we are still, Newton's words, like children playing with pebbles on the sea-shore, while the great ocean of truth rolls, unexplored, beyond our reach. (217)

I can offer no better conclusion than his:

> ... to travel hopefully is better than to arrive. (217)

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