On the Prospects for a Unified Theory of Physics: A Belated Response to Stephen Hawking

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Abstract

As theoretical physicist Stephen Hawking speculated on the prospects for a complete, unified theory in his 1988 book, *A Brief History of Time*, he appeared to embrace both scientific realism and instrumentalism. Since these two views in the philosophy of science are inconsistent, over the course of the next twenty-two years, Hawking modified his views until he arrived at his model-dependent realism, but he never resolved the inconsistency completely. In this paper I explain the inconsistency, respond to Hawking's criticism of philosophers of science and examine the key problems for a unified theory of physics.

Keywords: instrumentalism, scientific realism, model-dependent realism, unification of physics.[2]

> *If then, Socrates, amidst the many opinions about the gods and the generation of the universe, we are not able to give notions which are altogether and in every respect exact and consistent with one another, do not be surprised. Enough if we adduce probabilities as likely as any others, for we must remember that I who am the*

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speaker and you who are the judges are only mortal men, and we ought to accept the tale which is probable and inquire no further." —Plato, *Timaeus*, (29d)

1. Introduction

Stephen Hawking's contributions to theoretical physics earned him a place in the pantheon of great scientists. Like Einstein, he reflected on the general nature of physics, its philosophical implications and his expectations for a unified theory.

In 1989, I published a review of Hawking's blockbuster book, *A Brief History of Time,* in *The Review of Metaphysics.* I argued that there was an epistemic inconsistency in Hawking's views about a unified theory of physics in that he appeared to advance both an instrumentalist and realist position (1989, p. 627). Other scientists and philosophers made similar criticisms of Hawking after I published my review.[3]

In a lecture given at Caius College, Cambridge, in 1992 and published in *Black Holes and Baby Universes and Other Essays*, Hawking responded as follows:

> … I will discuss my approach to how one can understand the universe: what is the status and meaning of a grand unified theory, a 'theory of everything.' There is a real problem here. The people who ought to study and argue about such questions, the philosophers, have mostly not had enough mathematical background to keep up with modern developments in theoretical physics. There is a subspecies called philosophers of science who ought to be better equipped. But many of them are failed physicists who found it too hard to invent new theories and so took to writing about the philosophy of physics instead. They are still arguing about the

[3] Mendel Sachs, for example, who had worked on the unification of relativity theory and quantum mechanics criticized Hawking for exaggerating the extent to which a *final answer* toward a fundamental explanation of the universe is possible and argued that the stumbling block that is yet to be overcome is a major logical and mathematical incompatibility between the two theories. He wrote: "… in the *required* extension of quantum mechanics to relativistic quantum field theory, one arrives at a mathematical formulism that has no solutions—because of infinities that automatically appear" (1993, 544).

> scientific theories of the early years of this century, like relativity and quantum mechanics. They are not in touch with the present frontier of physics.
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> Maybe I'm being a bit harsh on philosophers, but they have not been very kind to me. My approach has been variously described as naïve and simpleminded. I have been variously called a nominalist, an instrumentalist, a positivist, a realist, and several other ists. The technique seems to be refutation by denigration: If you can attach a label to my approach, you don't' have to say what is wrong with it. Surely everyone knows the fatal errors of all those isms.
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> The people who actually make the advances in theoretical physics don't think in the categories that the philosophers and historians of science subsequently invent for them (1993, pp. 41-42).

In so far as Hawking ventured into the territory of philosophy of science, his view on the nature of theories was subject to criticism. Philosophers of science are not failed physicists; they are rather philosophers who examine a unique set of problems about the nature of science and scientific theories, its goals, scientific method and the metaphysical presuppositions of any scientific epoch. The two greatest philosophers of science of the twentieth century, Karl Popper and Thomas Kuhn were trained in physics but they and most others could not be described as failed physicists. It is not as if they were physicists who, having failed in their careers, then turned their attention to philosophy of science as a second career consolation. Popper's *Logic of Scientific Discovery* (1959) and Kuhn's *The Structure of Scientific Revolutions* (1962) are classics in the subject. Popper's work in particular had such an influence that it was endorsed by several distinguished scientists among whom Sir Herman Bondi, Sir Peter Medawar and Sir John Eccles were known in Britain as "The Popperian Knights." His conception of how science should function with the highest degree of rigorous testing of hypotheses and by facing up to the results of a negative experiment was widely praised by both philosophers and scientists.

What I think is right about Hawking's criticism is that philosophers of science should have a solid foundation in science lest their concerns become so esoteric and detached as to be of no relevance to the actual practice of science.[4] A philosophy *of* science depends on the existence of science in the first place. We might therefore describe the empirical inquiries of science as a first-order discipline, and the theoretical inquiries of the philosophy of science as a second-order discipline, but sometimes the boundary between theoretical physics and technical philosophy of science is hard to define. The limits of observation fade into pure theory.

I should not consider it denigrating nor a refutation to characterize a physicist's approach as nominalist, instrumentalist, positivist, or realist, but it is a problem to propose an inconsistent position. In order to clarify the different positions in Hawking's theorizing in the philosophy of science, we must distinguish between the following positions:

Realism—an objective reality, the external, physical world exists independently of mind or consciousness. Scientific realism claims that science aims to provide a literally true account of reality and that the entities postulated in confirmed scientific theories correspond to, or approximate, an external reality.

Instrumentalism— theories, models and concepts are useful instruments for explanations, predictions and problem solving but do not represent an objective reality independent of mind or consciousness.

Positivism—observational evidence is indispensable for knowledge of the world; our scientific theories are empirically confirmed by observation and experiment. Metaphysical claims are unverifiable and therefore should be eliminated from science.

Anti-realism —Scientific anti-realism claims that the unobservable entities postulated in scientific theories are instruments to aid the success of the theory but no claim of their existence.

Model-dependent realism—there is no theory-independent concept of reality and a physical theory is a model and a set of rules that connect the elements of the model to observations.

[4] Steven Weinberg agrees with Hawking that physicists are not guided much by philosophy, but that physicists do carry around with them a working philosophy, a rough-and-ready realism, i.e., a belief in the objective reality of the ingredients of their scientific theories (1992, p. 167).

2. The Nature of Scientific Theories

According to an incrementalist view, science over time accumulates an ever-increasing stock of truths whereby later science absorbs what was true in earlier theories and adds to it. Later science thereby becomes more correct than earlier science by getting closer to the objective truth. Both Popper and Kuhn, however, espoused an anti-incrementalism because the history of science tells another story. The major episodes of scientific revolution demonstrate the discontinuities in science. At best, for Popper, we have refutations of our theories but never confirmations. In other words, at a scientific revolution, such as the Copernican Revolution, the Einsteinian Revolution or the Darwinian Revolution, all bets are off with regard to what we previously believed to be true. In this respect, it would be naïve to believe that "we may now be near the end of the search for the ultimate laws of nature" (1988, p. 156). Hawking's optimism for a complete unified theory before the end of the twentieth century was obviously misplaced.[5] This, of course, is easier to see in retrospect from the perspective of the twenty-first century but the entire history of science already suggested that the achievement of a unified theory is never a final theory.

With respect to the inconsistency, Hawking offered strong epistemic confidence when he made assertions regarding a final theory or the end of particle physics. This we might call "realism with confirmation" or scientific realism, that there really is an external world to which our theories map onto and we get progressively better at the mapping of theory to observation and predictions. Scientific theories attempt to produce accurate representations of the world. This is exemplified by Hawking's optimism for a unified theory which he said we are now in a much better position to find because we know so much more about the universe (1988, p. 156) and we could be reasonably confident that a mathematically consistent theory that gave predictions that agreed with observations "would bring to an end a long and glorious chapter in the history of humanity's intellectual struggle to understand the universe" (1988, p. 167). Again, he wrote that "… it is reasonable to suppose that we might progress ever closer towards the laws that govern the universe" (1988, p. 12). And with regard to the search for elementary particles, he wrote: "… we do have some theoretical

[5] Also see Hawking's 1980 inaugural lecture as Lucasian Professor of Mathematics at Cambridge, "Is the End in Sight for Theoretical Physics," in which he expressed cautious optimism for a complete, consistent and unified theory by the end of the twentieth century (1993, pp. 49-68).

reasons for believing that we have, or are very near to, a knowledge of the ultimate building blocks of nature" (1988, p. 66) since an infinite sequence of more and more refined theories about ultimate particles is limited by gravity as we go to higher and higher energies (1988, p. 167).

On the other hand, Hawking offered weak epistemic confidence when he claimed that a physical theory is never proved, that it is "always provisional in the sense that it is only a hypothesis" (1988, p. 10). He alluded to the problem of induction when he wrote: "No matter how many times the results of experiments agree with some theory, you can never be sure that the next time the result will not contradict the theory" and refers to Popper's falsification—a theory is corroborated by an experiment but is never confirmed (1988, p. 10).[6] At best our theories are mathematically consistent and make predictions that agree with observations for a period of time (1988, p. 167). Hawking stated that scientific theories are just mathematical models we create to describe our observations, they exist only in our minds, and it is meaningless to ask which is more real since the choice depends on "which is the more useful description" (1988, p. 139). These comments suggest an instrumentalist position, that scientific theories are merely useful for explaining our observations and making predictions, but do not represent, or get closer to, an objective truth.

In *Black Holes and Baby Universes and Other Essays* published in 1993, Hawking explicitly addressed the realist-instrumentalist issue in what appears to be an attempt to resolve the inconsistency. In answering the question: "how can we make reality the basis of our philosophy?" he claimed he is a realist about the existence of an external world, but affirmed once again that "it makes no sense to ask if a theory corresponds to reality, because we do not know what reality is independent of a theory" (1993, p. 44), i.e., instrumentalism. But then in his book published with Leonard Mlodinow in 2010, *The Grand Design: New Answers to the Ultimate Questions of Life*, he wrote that "the universe has no single history,

[6] Hawking also endorsed Popper's philosophy of science, when he wrote: "Any sound scientific theory, whether of time or of any other concept, should in my opinion be based on the most workable philosophy of science: the positivist approach put forward by Karl Popper and others" (2001, p. 31). This statement is odd for two reasons: (i) he had already stated in 1993 that "[t]he people who actually make the advances in theoretical physics don't think in the categories that the philosophers and historians of science subsequently invent for them" (1993, pp. 41-42) and (ii) Popper was not a positivist. In fact, his key concept of falsification was the result of his criticism of the positivists' focus on confirmation.

nor even an independent existence" (2010, p. 6; also see pp. 34, 43-44). So, it appears that by 2010 Hawking had finally abandoned the commonsense notion of realism because quantum mechanics demanded its rejection (2010, pp. 5-6, 44, 140).

Hawking provided further clarification for what he called his "model-dependent realism," the view that there is no theory-independent concept of reality and that a physical theory is a model and a set of rules that connect the elements of the model to observations (2010, pp. 7, 42-43).[7] In this connection, Hawking and Mlodinow wrote:

> But there may be different ways in which one could model the same physical situation, with each employing different fundamental elements and concepts. If two such physical theories or models accurately predict the same events, one cannot be said to be more real than the other; we are free to use whichever model is most convenient (2010, p. 7).

This expresses the well-known Quine-Duhem thesis, "underdetermination of theory," in the philosophy of science, that any theory, hypothesis or model will always be underdetermined by the observational data or evidence. There will be innumerable theories, hypotheses and models (unlimited as there are unlimited scientific geniuses who will create them) and each of these will be compatible with the evidence but incompatible with one another (Duhem, [1914], 1954; Quine 1975).

Since this idea of model-dependent realism proposed that reality itself is impossible to reach, it is anti-realism (in spite of Hawking's use of the term "realism") and instrumentalism, and in these two books we see less of what I have called above "strong epistemic confidence."

[7] In 1996 Hawking had already expressed the basic idea for model-dependent realism in a debate with Roger Penrose when he wrote that: "a physical theory is just a mathematical model and it is meaningless to ask whether it corresponds to reality" (1996, p. 4). He described his position here as positivism rather than instrumentalism in contrast to Penrose's Platonism but model-independent realism is not positivism. Moreover, in *The Universe in a Nutshell*, Hawking repeatedly identified his approach as positivism (2001, pp. 118, 127, 180, 198-199) but positivism understood as confirming or falsifying a theory by experimental results (2001, p. 180) is conflated with the usefulness of a model (2001, pp. 127, 198). The definition of the positivist approach in the glossary— "the idea that a scientific theory is a mathematical model that describes and codifies the observations we make"— (2001, p. 201) together with positivism described as the idea that "[o]ne is free to use whichever model is most convenient" more accurately describes instrumentalism. (2001, p. 198).

There is also a striking affinity with Kuhn's position that there is no paradigm-independent concept of reality, but Kuhn himself struggled with the consequences of his own theory, namely, skepticism and relativism by those who attacked the objectivity of science (1962, pp. 205-207).

But then Hawking and Mlodinow end their book *The Grand Design* with an astonishing claim for M-Theory, "the *only* candidate for a complete, theory of the universe," which if "confirmed by observation, it will be the successful conclusion of a search going back more than 3,000 years. We will have found the grand design" (2010, p. 181). The use of the terms "confirmed" and "successful conclusion" within the context of the model-dependent realism still shows the original tension between the hopes for a final theory and instrumentalism. The notion that scientific theories can be confirmed remains in conflict with Hawking's acknowledgement that scientific theories can never be proved.

So, to be clear, it is inconsistent to maintain that scientific theories such as the Theory of Everything will bring about an end to theoretical physics and that scientific theories cannot be confirmed or proved. It is not inconsistent to believe in a mind-independent, external reality and that scientific theories cannot be confirmed, for a belief in an external reality does not conflict with the belief that our knowledge of that external reality is an endless series of conjectures and refutations or that we only have approximations to reality when theories appear to be confirmed. Hawking apparently attempted to resolve the inconsistency with his theory of model-dependent realism but the problem about confirmation remains.

Hawking famously and provocatively announced in *The Grand Design* that "philosophy is dead" since "it has not kept up with modern developments in science, particularly physics" (2010, p. 5). His point is that physicists have replaced philosophers in the quest for knowledge. While it is true that there are philosophers who attempt to discover the nature of reality by pure reason independently of science, others do keep up with modern developments in science. The latter group includes Bertrand Russell, Alfred North Whitehead, C. D. Broad, Rudolf Carnap, Karl Popper, Thomas Kuhn, and W. V. Quine from the twentieth century and Tim Maudlin, Nicholas Maxwell, Nancy Cartwright, Jeremy Butterfield and John Dupré today. There is no doubt that physics is at the cutting edge of reality, however, this has not left philosophers with nothing to do. But more importantly, and once again, Hawking himself, in venturing into the territory of philosophy by proposing his own theory about physical theories, is doing philosophy. For example, as Hawking became acutely aware of the complex interdependence between theory and observation, he advanced his model-dependent realism which has elements of instrumentalism, anti-realism and underdetermination of theory as noted above. He proposed a theory of perception which closely resembles John Locke's representative theory of perception (2010, pp. 46-47). And when he described the criteria for theory selection, "beautiful and elegant theories," as he called them, he included aesthetic qualities, logical consistency and empirical criteria such as agreement with observations, the ability to make predictions and comprehensive explanatory power (1993, p. 42). Here Hawking is not doing physics nor is he constructing a physical theory; he is rather engaging in meta-theory speculation which is a part of the philosophy of science. In other words, Hawking has gone beyond the physicist's quest to discover the nature of reality by engaging in philosophical speculation about a theory of theories. In his role of physicist replacing the philosopher, he has not only failed to defend a consistent position; he has also failed to acknowledge how much philosophy of science or epistemology informs or predates the position he is arguing.

3. Key Problems for a Unified Theory of Physics

Unified theories offer theoretical simplification achieved in the form of elegant equations and broad explanatory and predictive power**.** They are the central focus of theoretical physics and scientific progress is often measured in terms of success toward this goal. Some of the greatest advances in physics were achieved when previously believed separate phenomena were discovered to be aspects of the same phenomenon. At each step of a successful unification physicists appear to be on the right track, that the universe is comprehensible and the equations express an underlying beauty in nature. Celestial and terrestrial motions were united in Newton's law of gravitation. Electricity, magnetism and light were unified in the electromagnetic theories of Faraday and Maxwell. Mass and energy were fused in Einstein's special theory of relativity. Space and time were unified in his special and general theories of relativity. So, the quest for the Theory of Everything is a natural step in process but it has been one of the most complex and difficult challenges ever since Einstein sought and failed to unify general relativity and electromagnetism.

Hawking's proposal for the unification of physics in *A Brief History of Time* is the quantum theory of gravity, the theory that attempts to describe gravity according to the principles of quantum mechanics. In quantizing gravity—incorporating quantum fields into a curved space—there is the problem that relativity theory requires space-time to be smooth and continuous, but quantum mechanics requires quantization. In quantum field theory, the universe is comprised of fields and the waves within those fields come in discrete packets. The photon, for example, is theoretically a discrete wave-packet in the electromagnetic field. Incorporating gravity into quantum field theory requires that the waves in the gravitational field would also come in discrete wave-packets, hence the proposal for the hypothetical particle, the graviton. Physicists working on quantum gravity seek to describe the gravitational force in terms of quantum field theory, but a complete and mathematically consistent theory remains elusive and empirical testing is extremely difficult.

Another fundamental problem for any unification of modern physics is the problem of time because the two most difficult theories to reconcile — the general theory of relativity that describes the large-scale structure of the universe determined by gravity and quantum mechanics which describes the laws for the small-scale structure of the universe — propose two completely different theories. Time in general relativity is conceived as one aspect of the four-dimensional space-time, according to which time is inseparable from space-time and the flow of time is treated as an illusory subjective phenomenon whereas in quantum mechanics, time is understood as classical clock time, ticking away independent of a quantum system. In the former, nothing really happens because everything is already there—from the trajectories of subatomic particles to the revolutions of planets, stars and galaxies fixed eternally in the four-dimensional block. In the latter, however, something does happen at the collapse of the wave function that wasn't already there in reality. So, a consistent unification of time is required for the final link of unifying the Standard Model of particle physics with general relativity. Elsewhere I have argued that both quantum mechanics and general relativity require modifications in the concept of time in order to achieve this unification. Quantum mechanics must give up the classical clock time and general relativity must give up the block universe and the view that time is merely a subjective phenomenon (2015, pp. 87-98).

Hawking explained the main difficulty of unification as incorporating the uncertainty principle into general relativity since general relativity is a "classical" theory and quantum mechanics is not. (1988, pp. 156-157). Heisenberg's principle that it is impossible to measure both the velocity and position of a single particle at the same time introduced the element of chance or randomness into the universe. Hawking wrote: "In general, quantum mechanics does not predict a single definite result for an observation. Instead, it predicts a number of different possible outcomes and tells us how likely each of these is" (1988, p. 55). In other words, how do we reconcile the ontological determinism of general relativity with the probabilism in quantum mechanics? Einstein, in expressing his view that the universe operates according to a rigid determinism, famously complained of quantum mechanics: "God does not play dice with the universe." Nonetheless, the overwhelming majority of quantum physicists have affirmed the probabilistic nature of the quantum world.[8] The creators of quantum mechanics, Bohr, Heisenberg, Schrödinger and Dirac agreed that the quantum domain is made up of quantum entities – electrons, photons, atoms—that are different in character than anything in deterministic classical physics. This is sometimes called "quantum weirdness." While quantum mechanics is notoriously difficult to characterize due to so many interpretations of it,[9] in one version advanced by Heisenberg, quantum entities are probabilistic entities in that the evolution and collapse of the wave function is characterized as a transition from the possible to the actual (1958, pp. 54-55).

The determinism/probabilism problem is built into the problem of two different theories of time, since general relativity is deterministic, with past, present and future all ontologically fixed in the four-dimensional space-time and the probabilistic quantum theory proposes an open future for the evolution of quantum states.

This leads to the question: what is time in Hawking's *A Brief History of Time*? His view of time in the proposed quantum theory of gravity involves two essential features: (i) Feynman's formulation of the quantum theory in terms of a sum over histories approach, modified by his proposal of "imaginary time," according to which waves for particle histories are measured using imaginary numbers rather than real ones, and (ii) Einstein's theory of general relativity as a representation of the structure of the gravitational field. Feynman's

[8] Hawking affirmed the probabilistic nature of quantum mechanics when he argued "no matter how much information we obtain or how powerful our computing abilities, the outcomes of physical processes cannot be predicted with certainty because they are not determined with certainty. Instead, given the initial state of a system, nature determines its future state through a process that is fundamentally uncertain" (2010, p. 72).

[9] The Copenhagen Interpretation, the pilot-wave ontology, the many-worlds ontology, the spontaneous-reduction models, relativistic quantum field theory, and the actual events ontology, for example.

sum over histories applied to Einstein's theory of gravity results in a view of the history of particles in a curved space-time that represents the history of the whole universe.

Imaginary time is required because matter and energy produce a spacetime curved in on itself. Since real time leads to singularities where the laws of physics don't work and we cannot make predictions, imaginary time allows us to explain how the three space directions and the imaginary time direction would form a spacetime that was closed in on itself, without boundaries nor edges, nor any beginning or end (1988, p. 141; 1993, p. 82). The universe is thus self-contained and in imaginary time, there is no important difference between the forward and backwards directions (1989, pp. 143-144). Hawking claimed that imaginary time, while difficult to grasp, will one day become an "intellectual leap of the same order as believing that the world is round" (1993, pp. 81-82). His comparison of the globe with the expanding universe in increasing imaginary time shows a block universe whereby all events exist in a four-dimensional spacetime (1988, p. 138, 2001, pp. 90-94). In this respect his position appears to agree with eternalism in the philosophy of time, all events—past, present and future—are present, but how does this square with cosmic time, asymmetry, the arrow of time and the open future?

Some physical laws do not distinguish between the past and the future and therefore support the concept of symmetry in nature. In classical mechanics, for example, the law $F = ma$ is symmetrical in the sense that it describes the motion of particles or macroscopic bodies without regard to any direction in time. Any physical process described by this law is equally described by a time-reversed process. But now the question is whether all of physics works in this way. Other laws support an asymmetry in time or an arrow of time, such as thermodynamics in which disorder or entropy increases, in quantum mechanics where we observe the collapse of the wave function and the decay of radioactive elements, and in cosmology where the universe is expanding rather than contracting. Moreover, beyond physics there is evidence for asymmetry in psychology where we remember backwards not forwards and in causation, effects are always preceded by causes and never the reverse. So, the question is: which laws are fundamental or have an overriding status in the depiction of reality? Hawking argued that the psychological, thermodynamic and cosmological arrows of time support a real direction of time in spite of the fact that many laws of physics do not distinguish between a forward and a backward direction of time. In appealing to the weak anthropic principle and the expansion of the universe, Hawking contended that only when the universe is expanding does it support life and the existence of intelligent beings who contemplate the direction of time (1988, pp. 151-152). We are here; therefore, the universe is constructed such that intelligent life is possible. In the expansive phase we experience time in accordance with the thermodynamic and cosmological arrow (1988, pp. 145, 152). Disorder increases with the direction of time.

What happens then when the universe is contracting? The idea of expanding and contacting phases of the universe appeared to offer another example of symmetry in physical laws, but theoretically, there is still a direction of time. Hawking argued first that the no boundary condition would mean that there is an arrow of time that would reverse at the contraction of the universe (1985). But then he changed his position because fluctuations in the no boundary state would continue to grow in a phase of contraction so that the thermodynamic arrow of time still points in a constant direction regardless of whether the universe is expanding or contacting (1993). Disorder would continue to increase and the thermodynamic and psychological arrow of time would not reverse (1988, p. 150). So, the direction of time is not merely a subjective illusion since it is based on something in reality – the thermodynamic arrow. But this still leaves us with the unanswered question regarding the open future and the uncertainty principle, i.e., randomness or chance. To be clear this is not an epistemological matter of predicting future events, but rather a question of ontological status of the future.

Progress on a unified theory for the most part stalled after the unification of electromagnetism and the weak nuclear force by Glashow, Weinberg and Salam in 1967. The unification of the strong nuclear force in the Standard Model (Grand Unified Theory) and the big problem of unification with general relativity (Theory of Everything) remain unsolved.

Weinberg observed that physicists, in their search for the final theory, are more like hounds sniffing about the ground rather than hawks high above seeing general patterns in philosophy (1994, p. 167). In his chapter "Facing Finality" of *Dreams of a Final Theory*, like Hawking he expressed his optimism for a final theory based on the success of physics in the twentieth century that provided "a convergence of arrows of explanation" and principles that have steadily become simpler and more economical. These arrows, he contends, must converge somewhere (1994, pp. 231-232). As he made his case, he argued: "The discovery of the final laws of nature will mark a discontinuity in human intellectual history, the sharpest that has occurred since the beginning of modern science in the seventeenth century" (1994, p. 235).

But instead of appealing to the limits of human intelligence, the main problem is the limits of financial resources to build the Super Collider that would be instrumental in the discovery of a final theory.[10] The Planck energy of a hundred trillion times higher than the energy of any Super Collider, where all the forces are expected to be unified in one force, is beyond any accelerator now conceivable (1994, p. 234).

As for the shape of a unified theory, if and when it happens, it seems likely that:

(1) as Einstein predicted, it will be some kind of field theory,

(2) either relativity theory or orthodox quantum theory (or both) will need to be modified,

(3) the question about the nature of time will be fundamental; either time will be treated as an illusion, a local phenomenon of a multi-dimensional universe (or multiverse) or it will figure as a key feature of reality,

(4) the theory must reconcile the uncertainty principle with the theory of gravity,

(5) the theory will provide testable predictions, and

(6) the theory will exhibit broad explanatory power covering both the large-scale and small-scale structure of the universe.

It is of course possible, indeed most probable, that there is no *final*, unified theory, but only (i) an endless sequence of theories or (ii) different partial theories of physics describing different aspects of reality, with no overall ability to provide comprehensive explanations.[11]

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[10] In 1992 the US government cancelled the Super Collider project when the cost rose from the original estimate of $4.4 billion to $8.25 billion. The proposed €9 billion to €21 billion Future Circular Collider at CERN has yet to be funded. See https://home.cern/science/accelerators/future-circular-collider

[11] With regard to (i), Popper, for example, doubts the idea of a final theory or ultimate explanations. Instead, he argued that every explanation may be "further explained by a theory or conjecture of a higher degree of universality. There can be no explanation which is not in need of a further explanation…." (1972, p. 195). Furthermore, he wrote: "… although I do not think that we can ever describe, by our universal laws, an *ultimate* essence of the world, I do not doubt that we may seek to probe deeper and deeper into the structure of our world or, as we might say, into properties of the world that are more and more essential, or of greater and greater depth (1972, p. 196).

With regard to (ii), Hawking and Mlodinow described M-Theory as a network of theories, each one of which is adequate for describing phenomena within a particular range, but no single theory within the network describes every aspect of the universe, even though some theories overlap in explaining diverse physical phenomena. While M-theory has been understood to be a quantum theory of gravity and a leading contender for a Theory

Just as Newton, or Aristotle before him, provided a coherent paradigm that gave unity and direction to physics for a time, so will the unification of relativity and quantum theory if and when it occurs. A "final" theory simply means the final step of unification in the current attempt to develop a comprehensive paradigm, not a final theory of physics. Any physical theory will face the inevitable decay of the framework and the shock of a scientific revolution. In this connection, the ancient wisdom from Plato's *Timaeus*, quoted at the beginning of this paper, that science, and in particular any cosmological account as to the beginning of the universe, is a likely story, rings true (1953, 640-641). The second alternative (ii) presents a more challenging claim, but if we can make the very plausible assumption that nature itself is unified and intelligible, history would appear to be on the side of those who have achieved unified theories, themselves parts of other more general theories. If the first alternative (i) is correct, it is no deterrent to the endless quest of both science and metaphysics.

4. Conclusions

In this paper I argued that the inconsistency in Hawking's philosophy of science in 1988 was addressed in his subsequent writings but was never resolved. His optimism for a confirmed, final, unified theory was repeated as late as 2010, yet the model-independent realism he embraced at this time conflicts with this claim. Since model-independent realism is a form of instrumentalism and anti-realism, it stands as fundamentally incompatible with realism in spite of its paradoxical name. I also examined some of the problems with the herculean task of a Theory of Everything and the prospects for its success. The main contender endorsed by Hawking, a quantum theory of gravity, must solve fundamental problems with the incompatibility of quantum mechanics and the general theory of relativity, but at present, the issues relating to the nature of time and the probabilistic versus deterministic formulations of quantum mechanics and general relativity remain insurmountable. Hawking's proposal of imaginary time does not appear to solve the

of Everything, Hawking and Mlodinow view it as not fulfilling the dream of any such complete unified theory (2010, p. 58). Moreover, as Hawking and Mlodinow considered prospects for the Theory of Everything, M-Theory, based on the multiverse conjecture, with laws for 10^{100} different universes, only one of which corresponds to what we know as our universe, they suggest that the hope for a single theory may have to be abandoned (2010, pp. 117, 119).

probabilism/determinism problem because it does not account for the open future and the uncertainty principle required by quantum mechanics.

Physicists who dabble in philosophy are likely to miss the subtleties of the various philosophical positions and the complexity of the arguments advanced in support of or against the positions. Philosophers who dabble in physics, as Hawking charged, are likely to fail in understanding the complex mathematics in which physical theories are expressed and the sheer complexity of those theories, especially at the cutting-edge of physics. Both groups risk their dignity in any such interdisciplinary endeavors, myself included.

In response to physicists such as Hawking and Weinberg who claim that philosophy provides no useful guidance to science, it is more a matter of what the right kind of philosophy has to offer, namely, a scientifically informed metaphysics rather than bad philosophy. There is no escape from philosophy in the same way that there is no escape from some conceptual framework by which we interpret our experience.

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