Cosmic If Statements

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Foreword

This paper discusses and proposes controversial ideas that will fall outside the comfort zone of some readers. Nevertheless, the arguments are logically sound and derive from much interaction with the works of John Polkinghorne and are consistent (as I shall argue) with his scientific and theological position. With that said, and since this paper is written in recognition of Polkinghorne's contributions to the field, it will be expedient to begin by appealing to his sense of open-mindedness:

> Metaphysical endeavour in general, and talk of agency in particular, will inevitably require a certain boldness of conjecture as part of the heuristic exploration of possibility. In our present state of ignorance, no one has access to a final and definitive proposal. The test of the enterprise will be the degree to which it can attain comprehensiveness of explanation and overall coherence, including an adequate degree of consonance with human experience.[1]

It is important to lay out the central conceptual scheme right from the start as it aims to establish clarity in the complex topic of God's relation to the world. From there, I can begin to interact with the works of Polkinghorne more directly, making points of contact between his ideas and the scheme at hand, before developing the final practical challenge that Polkinghorne and others can present to progressive creationists such as proponents of Intelligent Design.

[1] J. C. Polkinghorne, "The Metaphysics Of Divine Action", in *Chaos and complexity: scientific perspectives on divine action*, ed. R. J. Russell, N. Murphy and A. R. Peacocke (California: Vatican Observatory Publications & Berkeley, 2000), 147.

1 The Cosmic Computer

1.1 Representing Universes

The observation that the physical world resembles a computer program goes back to the very early pioneers of information science.[2] The connection goes as follows. The Universe, viewed from the perspective of Newtonian physics, consists of objectively existing particles in motion having well-defined (even if unknown) positions and momenta with respect to some fixed coordinate. One of the most remarkable features of this (Newtonian) Universe[3] is that, somehow, it keeps track of a seemingly vast array of numbers[4] that get updated according to specific rules. As Laplace famously pointed out, in such a world the future state of the Universe is in principle discernible given perfect knowledge of the present state (that is, the values of each number in the cosmic array), the physical laws that relate the state of the Universe from one moment to the next, and unrestricted computational power.

Quantum Mechanics and General Relativity complicate the details, but the overall idea remains the same: the physical Universe can be effectively represented as an array of numbers[5] that get updated at each temporal slice by a set of rules that the physicist seeks to express through mathematical operators.[6] [7]

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[2] Such as von Neumann. For a masterful account of the history and development of this subject, I thoroughly recommend chapters 4, 5 and 6 of Paul Davies' *The Mind of God*.

[3] I shall use universe with a capital 'U' in contexts where there is an intended sense of isolatability or uniqueness, otherwise with a small 'u' for those belonging to an ensemble of either putative universes or those belonging to a Multiverse. This distinction is *not* fundamental to the essay.

[4] To be precise, 6 numbers for every particle and thus an infinity of numbers if the Universe has an infinite number of particles. This is commonly referred to as the "phase space" of the physical system.

[5] In these cases, namely, the amplitudes of wave-functions in Quantum Mechanics and the metric of the space-time manifold in General Relativity. The scheme works best if space-time is ultimately quantised but can still prove illustrative even if it is not.

[6] If QM is intrinsically probabilistic, then the rules would have to include a 'random number generator,' and would mean that the future state is in principle unknowable given the present state, but this does not invalidate the conceptual scheme.

[7] Some might argue that relativity invalidates the notion that you can carve up the world into temporal slices due to the relativity of simultaneity. I do not believe that this is a major conceptual issue since, even in the Block Universe, there is a notion of causality that can used to relate hypersurfaces. See C. J. Isham and J. C. Polkinghorne, "The Debate Over The Block Universe", in *Quantum Cosmology And The Laws Of Nature*, ed. R. J. Russell, N. Murphy

This provides a useful scheme for conceptualising the physical form of possible worlds.[8] Any hypothetical universe that is logically possible can be physically represented by a particular array of numbers that gets updated by a particular set of rules. In the case of our Universe, these would correspond to boundary conditions and physical laws in ordinary scientific parlance.

An important notion in what follows is to speak of the complexity of any such representation. It seems conceptually feasible to formulate some measure[9] or, at the very least, some qualitative notion of the complexity of these representations of universes. Whether there is a natural or unique way to construe such a measure is not essential for the purposes of this discussion. It is sufficient to point out that any such measure would need to do justice to intuitive notions such as 'information compressibility' (to what extent can an array of numbers can be reduced to a non-redundant representation of its information content) and rules that make use of primitive mathematical operators, etc. This is connected to the notion of 'algorithmic compressibility.' As Barrow explains,

> [Science is] predicated upon the belief that the Universe is algorithmically compressible and the modern search for a Theory of Everything is the ultimate expression of that belief, a belief that there is an abbreviated representation of the logic behind the Universe's properties that can be written down in finite form by human beings.[10]

Unfortunately, attempts to formalise physics in this way are frought with practical and conceptual difficulties and so the notion of measuring the 'complexity' of the Universe remains a merely qualitative, though deeply illustrative, concept.

Assuming we had such a measure, one could categorise any possible world in relation to ours by its comparative complexity. For example, a world that is like ours in every way except that random macroscopic objects appear *ex nihilo* at different places and times is perfectly representable in this scheme, the only difference is that such a world is relatively *complex* compared to ours. Such a world would demand more 'disk space' in the cosmic hard drive and/or

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and Isham C. J. (California: Vatican Observatory Publications & Berkeley, 1996), 139, for discussion.

[8] Whether or not this scheme is adequate to describe all aspects of the non-physical world, such as the presence of consciousness amidst the particles that make up the human brain, will largely depend on the truth or falsity of mind-brain reductionism. Hence I qualify this scheme, stated thus far, as a representation only for the *physical* state of a universe.

[9] That is, some way of mapping the array of numbers and algorithms ('physical laws') that update that array in any given representation of a universe onto the real number line whose value can be compared to others using the 'greater-than', 'less-than' or 'equal-to' operators.

[10] J. D. Barrow, *Theories of Everything* (Oxford: Oxford University Press, 1991), 11.

physical laws with sharp discontinuities and extra terms that are carefully weighted so as to be negligible except in particular locations in space and time. The reverse engineering (figuring out the rules) and expressing them mathematically would be indescribably more difficult and likely impossible in practice. Nonetheless, there is nothing conceptually incoherent about such worlds.

1.2 The Computational Analogy

This representation of the physical Universe is strikingly analogous to the running of a program on a computer. A computer program in operation is, viewed from one perspective, an array of numbers corresponding to pixels on a screen that get's updated according to a set of rules specified in the computer code. Unlike the Universe though, whose numbers get updated by a set of very consistent physical laws that we cannot alter, computer code is, in general, only constrained by the loose requirement of self-consistency. The universal-computer analogy therefore leads to a powerful means with which to explore the space of conceptual possibilities. As Stephen Wolfram explains,

> Executing a computer program is much like performing an experiment. Unlike the physical objects in a conventional experiment, however, the objects in a computer experiment are not bound by the laws of nature. Instead they follow the laws embodied in the computer program, which can be of any consistent form. Computation thus extends the realm of experimental science: it allows experiments to be performed in a hypothetical universe... [as such] Scientific laws are now being viewed as algorithms... processing information much the way computers do. New aspects of natural phenomena have been made accessible to investigation. A new paradigm has been born.[11]

I wish to argue that this conceptual approach to the functioning of the world has much promise not just for understanding science, but also theology. In particular, it can shed light on the nature of miracles and God's interaction with the world. Before delving into details, I wish to make two comments regarding this conceptual scheme.

Firstly, it is metaphysically neutral.[12] A representation by itself says nothing about the origin of any given universe or why that universe complies with that particular representation rather than

[11] Wolfram S., "Computer Software in Science and Mathematics," Scientific American, 1984, accessed 29th March 2010, http://www.stephenwolfram.com/publications/articles/general/84-computer/2/text.html

[12] Or, at least, about as metaphysically neutral as you can get. Modern science owes much of its success to its eschewal of metaphysical presuppositions (such as Aristotle's notion that Nature strives towards 'the Good') in ascertaining the evolution of physical systems. Instead,

some other. The representation merely *describes* - it does not *explain*. Secondly, and of particular relevance to theism, a universe in which apparent miracles occur (say, those akin to macroscopic appearances *ex nihilo*) are those having relatively complicated representations in terms of information content and evolutionary laws. That is, in some sense, a miraculous world is equivalent to (or perhaps indistinguishable from) a complicated world; miracles in this perspective are the *complication* rather than the *contravention* of physical law.

How then does the computational-universe analogy link in with God's interaction with the world? From the perspective of the software engineer, the array of numbers corresponding to the pixels on a computer screen get's updated according to a set of abstract rules that are decided, ultimately, by the will of the programmer. The patterns on the screen thus express the character, propensities and desires of the programmer as well as any external constraints that he/she might be subject to. In this analogy then, the screen is to the programmer what the Universe is to God - a canvas on which one's creative will can be expressed. By choosing the right initial array of numbers (the 'state' vector) and appropriate laws with which to evolve the vector, God can

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the (classical) scientific method proceeds by representing physical systems at different moments in time by numbers (quantifying the position/density of a particle/substance) as (would be) measured by experimentation and then linking these sets of numbers with the simplest mathematical relationships (represented by the single-width arrows in the diagram). The scheme is therefore not entirely metaphysically neutral since it constantly imposes a preference for mathematical simplicity upon Nature that, time and time again, has eventually proved inadequate to save all the phenomena. Moreover, since this method can work *only* by assuming the tractability of Nature, the scientific method has developed so as to turn this need around and treat it as axiomatic (e.g. by insisting on the 'smoothness' (differentiability) of space-time and amplitudes in (quantum) field theory). This essentially pragmatic approach to the functioning of Nature means that discontinuities (e.g. the Big Bang singularity, collapse of the wave function, etc.), when encountered, are taken to be non-physical artefacts of mathematical representations that approximate a deeper, more unified theory. As such, mathematical simplicity and tractability have tacitly become the metaphysical presuppositions that govern the practice of (hard) science.

$$\begin{bmatrix} 1 \\ 2 \\ 3 \\ \ldots \\ 8 \end{bmatrix} \rightarrow \begin{bmatrix} 2 \\ 3 \\ 4 \\ \ldots \\ 9 \end{bmatrix} \Rightarrow \text{abstract the patterns } \Rightarrow \psi \rightarrow \psi'$$

actualise any self-consistent universe.[13] The form and contents of the Universe thereby reflect the character, nature and desires of the Creator[14] as well as any constraints he might be subject to.

What might these constraints be? When humans program, they are constrained by the speed of their computer, the limits of their memory and the fact that, in order to attain a certain degree of complexity with respect to the image on the screen, there will always be a minimal amount of corresponding complexity in the code (a rough measure of this complexity would be the number of lines of code required to achieve the desired pattern on the screen). A human will thus attempt a trade-off between these various constraints in order to minimise memory usage and produce code that is elegant and easy to decipher whilst achieving the intended screen pattern. There is most definitely an art to programming[15] and one of the key aesthetic practices is to use, generally speaking, as few lines of code as possible, eliminating redundancies whenever they crop up.

It is of particular importance to this discussion to point out that the programmer cannot compress the code to an arbitrary degree *and* retain full functionality in the desired screen pattern. For any non-trivial program expressed in some language, there is always a minimal complexity required in the code, as well as a minimal amount of memory space used at any one time beyond which no compressibility is possible without compromising full functionality.[16]

The programmer of the Universe is constrained for different, though analogous, reasons. A God who desires free-willed and intentionalistic creatures to function rationally within the Universe is constrained to make the operation of its natural processes consistent enough to allow for sound inductive reasoning. This places an *upper limit* on the complexity of the physical laws that govern the Universe. If there are too many discontinuities and apparently uncorrelated events,

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[13] Of course, God is not just a software engineer, but a hardware engineer as well; once he has decided what abstract rules are to govern the evolution of the Universe, he can then actualise whatever metaphysical substances would be needed to reflect (or behave according to) those abstract relationships.

[14] For example, God might find a Universe that evolves its state vector using a random number generator (*viz.* quantum mechanics) more interesting than a strictly deterministic world.

[15] It is difficult to convey this aesthetic sense to those without much background in programming; it is akin to the elegance that mathematicians speak of, as Polkinghorne himself says, "This is a concept not all will find accesible, but among those of who speak the language of mathematics, mathematical beauty is a recognizable quality," J. C. Polkinghorne, *Beyond Science* (Cambridge: Cambridge University Press, 1998), 79.

[16] Imagine challenging a programmer to write an adventure game using only ten lines of code – the fact that this is impossible in no way reflects a deficiency in the programmer; it is simply too great a constraint. Similarly, the fact that God cannot beat me at chess just starting with a king and a pawn hardly calls into question his omniscience, it would simply be a constraint such that no possible combinations of moves would be available to God that could beat me.

the deciphering of any pattern becomes too difficult and all sense of moral responsibility gets obscured in the unpredictable chaos that ensues.

At the same time, there is a minimal degree of complexity required by the Creator to make the world sufficiently interesting. A Newtonian universe consisting of two particles would be simple enough for physically-grounded creatures to figure out, but not complex enough to furnish their existence. There is thus an anthropic *lower limit* on the complexity of the Universe corresponding to some minimal size of array of numbers representing the physical state of the cosmos and/or a minimal degree of complexity in the laws that evolve one temporal slice of the world to the next.[17]

Thus we find that the (weak) anthropic principle[18] - the fact that Universe must be such as to allow us (who observe it) to exist - calls into question the long held assumption of science that continued thought and research will simplify our physical theories to an arbitrarily great extent whilst saving the phenomena. If we have not already essentially reached this ‘complexity limit’ with our current state of knowledge, we will do so eventually. Consideration of this minimal complexity and the computer-analogy that gave rise to it therefore motivates us to consider how it is that complexity is most efficiently encoded in computer science.

1.3 If Statements

An invaluable concept found in virtually all programming languages is an ‘if-statement.’ These control the execution of a program by asking whether a particular condition has been met and act thereby as ‘switches’ between different regimes of behaviour. It is difficult to overestimate how important if-statements are in computer science. They simplify programming to such an extent that it would be a safe to say that computer software would be inefficient to the point of uselessness without them. This is because they allow a degree of non-linearity in the complexity

[17] Elsewhere Barrow makes a point along similar lines, “Just as the most expert computer programmer is the one who can write the shortest program to effect a particular task, so we might expect the Architect of the ultimate program that we call the laws of nature to be elegantly economical on logic and raw materials. It is a common tendency to think that it would be a hallmark of the universe's profundity if it were unfathomably complicated, but this is a strange prejudice. This view is motivated by the idea that the Creator needs to be superhuman - and what better way to assert that superiority than by incomprehensibility? But why should that be so? Anyone can explain how to assemble a model aircraft in 500 pages of instructions; it is not so easy to do it in 10 lines. Profound simplicity is far more impressive than profound complexity.” J. D. Barrow, *Impossibility: the limits of science and the science of limits*, (London: Vintage Press, 2005), 76-7.

[18] See J. D. Barrow and F. J. Tipler, The Anthropic Cosmological Principle (New York: Oxford University Press, 1996), 16, for definition and discussion.

of the code that would otherwise require copious amounts of memory and/or computational power.

One can readily see that this is the case by considering a simple step-function f(x) involving an if-statement, such as

$$f(x) = \begin{cases} 1, \text{ if } |x| < 1 \\ 0, \text{ otherwise.} \end{cases} \tag{1}$$

An equivalent mathematical representation of the same function can be found by taking the Fourier transform. In this case, the same function takes the form

$$f(x) = \sum_{n=1}^{\infty} a_n \sin(nx + \phi) \tag{2}$$

This does away with the (sharp/discontinuous) if-statement but requires an *infinite* number of (smooth/continuous) terms to precisely reproduce the same graph. Thus, it is far simpler and more efficient, computationally speaking, to use an if-statement here. This is a general result. The functionality achieved by using an if-statement can *always* be achieved in principle without it by complicating one's code and so, in some sense, the effects of if-statements are connected to (or perhaps indistinguishable from) complexity. In the case of human programming, given the constraints of computing power available to us it would be impossible, practically speaking, to achieve much non-linear complexity without them (we can't carry out an infinite number of calculations).

Given the close analogy then between the physical laws of the Universe and the functioning of a computer program noted previously, the question naturally presents itself as to whether or not the physical laws of the Universe possess if-statements (or laws so complex so as to be indistinguishable from if-statements). And if so, where and to what extent do they occur? Perhaps it is the case that the minimal complexity of the Universe necessitated by the Anthropic Principle is such that if-statements (or effects that are indistinguishable from if-statements) are required to write down its representation in its most compact form. Their effects could even give rise to phenomena that appear to be genuinely emergent from the view point of contemporary science that tries to reduce everything to 'fundamental laws' like the Schrödinger equation.[19] Such if-statements could thus form a sort of 'biotonic law' - a term coined by the biologist Walter Elsasser who believed that regularities persist in biological phenomena that cannot be derived from the (fundamental) laws of physics.[20] *A priori*, there is no way to know if the most compact

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[19] Note that, in this essay, I shall treat Schrödinger's equation as an archetype for a fundamental law of physics from which scientists typically try to explain higher-level physical phenomena such as biochemistry. One could of course point to even more fundamental equations such as Dirac's, but my purpose here is merely illustrative.

[20] By 'genuinely emergent' effects I mean effects/properties that would not be predictible or

representation of the Universe would need to involve if-statements. From the theistic perspective, it may be that God *had* to use them, not because of any deficit in his capabilities, but because it is the simplest way to encode the necessary complexity for life to arise in the Universe. Just as God cannot make carbon-based life in a Newtonian world with only two particles left to run their own course, so perhaps it is not possible for a world like ours to incur self-organised complexity to the extent observed without emergent behaviour that 'switches on' in certain regimes of physics. One can then go one step further and ask whether there is the philosophical-theological possibility that *mental*, *spiritual* or *moral* states of affair control these 'phase changes', to borrow Polkinghorne's analogy, in the laws of nature.

To summarise so far, I have laid out a scheme for representing universes and pointed out that a universe where miracles appear to happen can be construed as a universe that follows consistent laws only that these laws are *complicated* (probably to the point of being intractable). I also pointed out that there is a connection between complexity and the implementation of if-statements in programming. This leads to the question as to whether the minimal complexity required by the Anthropic Principle could require the implementation of if-statements in the most concise representation of the laws of nature. It also raises the prospect of understanding miracles as phenomena where apparent departures from the laws of physics are not actual departures, but the fulfilment of conditions operated on by cosmic if-statements.

In the remainder of the essay, I shall explore these connections between complexity, divine interaction and the Anthropic Principle in their conceptual relationship to if-statements in representations of the world in analogy to a computer program, examining both the theological motivation as well as scientific motivation to suppose that such 'phase changes' might actually be embedded in the structure of the world.

2 Theological Motivation For Cosmic If Statements

2.1 Matter's Bias And The Reductionist Stance

The antithesis of the scheme presented in this essay is reductionism - particularly with respect to biological complexity - and so a short exposition on this subject will prove useful. In *Science and Providence*, Polkinghorne reflects on the following excerpt by Montefiore:

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determinable from their underlying constituents *in principle.* By contrast I do *not* mean statements of epistemological limitation or convenience. It is debatable whether Elsasser understood biotonic laws in this 'genuinely emergent' way. I will assume he did in this essay in making reference to such laws.

> Although there is no external force imposed on species, and in particular on their genetic systems, mutations occur which would not be expected by random mutation. This is not because of external pressure, but because of the bias implanted in matter. Such bias is not, of course, to be detected by scientific measurement (and so the hypothesis is not testable) since there is no possibility of setting alongside it matter which is not implanted by the bias towards complexity and integration.[21]

What is the essence of this 'bias' to which Montefiore refers? According to him, there is an intuitive sense in which the propensities of physical systems to generate biological complexity go against our *a priori* expectations. But how well founded are these expectations? Is this essentially a statement of our ignorance of the physical structure of the world? In scientific inference, outcomes of measurements of systems that we know little (or nothing) about are usually treated with a flat probability distribution, that is, they're assumed to be equally likely. For example, the probability of getting a particular roll of a die is usually treated as 1/6 until there is reason to believe that the die is sufficiently irregular so as to break the physical symmetry and result in some preferred configuration. In virtue of this extra information (that the die is loaded), we are then no longer surprised by the bias it exhibits.[22] As Polkinghorne comments,

> Another way of describing the 'bias' would be... simply to call it 'scientific law'... There is no absolute expectation of randomness; the odds of chance events are to be calculated in relation to some lawful expectation. If I know the die is loaded I shall do my calculations differently from the way I would if I thought the die were true.[23]

The 'unexpected' is thus connected, sometimes at least, with one's ignorance of all the facts. We don't know how matter operates in all its intricacies, so our imaginations conjure up some notion of impotent and unreactive matter with a flat-prior "not implanted by the bias." But as Polkinghorne points out, matter without the bias would not be matter - matter is not structureless but does what it does because of the fundamental laws of physics. Does that then mean that no matter what we observe in the functioning of nature, however *prima facie* unexpected it might seem, we must (in some sense that lies at the centre of the debate) suppress any sense of surprise?

From the viewpoint of the ardent reductionist the answer is yes - there is never any *intrinsic* mystery to be found in higher-level processes such as biological functioning. Any sense of 'surprise,' no matter how great, is taken by the reductionist to indicate not that biology is irreducible to fundamental physics but that we are simply ignorant of the all the underlying facts.

[21] Quoted by J. C. Polkinghorne, *Science and Providence* (London: SPCK, 1989), 38.
[22] This is "a "throwing away of the prior," as Bayesians say," B. C. van Fraassen, *The Empirical Stance* (New Haven: Yale University Press, 2002), 92.
[23] Polkinghorne, *Science and Providence*, 38.

Surprise tells the reductionist where research is still needed and reinforced expectation where none more is required. Since phenomena can always be consistently shelved into one of these two categories (reduced and not-yet-reduced), it is clear that reductionism can never be disproven.

Reductionism is not only unfalsifiable, it is also transparently circular. It only "explains" phenomena, ultimately, by positing entities equipped with just those properties that will reproduce the observed phenomena. The enterprise would therefore be rather suspect were it not for its tremendous success at *unifying*[24] so many seemingly disparate phenomena into so concise a conceptual scheme as given by modern science. As Polkinghorne remarks, "the understanding gained thereby proves that this circularity is benign and not vicious."[25] At the same time, Polkinghorne is careful to note the pragmatic nature of reductionism and that it therefore need not infringe on a broader view of the world:

> It is clearly worthwhile to pursue the program of reductionist explanation as far as it can legitimately be pursued, but that is a methodological strategy for investigation, not a metaphysical strategy determining the total nature of reality.[26]

In short, reductionism *gets results* and so we tend to overlook its question-begging shortfalls in virtue of other qualities such as "elegance, economy and naturalness."[27]

By the very nature of the program then, it is no surprise that with the progression of reductionist science there follows a general shift of mystery away from higher-level phenomena (of biology say) towards the lower-level phenomena of elementary particle physics.[28] The long hope of many scientists is that all the mystery and surprise in Nature would eventually disapear in some 'Theory of Everything' as envisioned by Steven Weinberg.

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[24] The view of (scientific) explanation being endorsed here is that which emphasises the central (though difficult to expound) concept of unification. A summary statement might be "[s]cience advances our understanding of nature by showing us how to derive descriptions of many phenomena, using the same pattern of derivation again and again." P. Kitcher, *Scientific Explanation*, ed. Kitcher & Salmon (Minnesota: Univ. of Minn. Press, 1989), 423.

[25] J. C. Polkinghorne, *Belief in God in an Age of Science* (USA: Yale University Press, 1998), 107.

[26] Polkinghorne, "The Metaphysics Of Divine Action", 150.

[27] Polkinghorne speaking on the problem of underdetermination, Polkinghorne, *Belief in God in an Age of Science*, 16.

[28] That is, the parts of Nature that are readily-reducible get reduced and the rest gets stacked on the 'to-reduce' pile.

> A fundamental theory [of everything] has to be simple - not necessarily a few short equations, but equations that are based on a simple physical principle... it has to give us the feeling that it could scarcely be different from what it is.[29]

Increasingly though, this metaphysical aspiration is being abandoned in virtue of the Anthropic Principle (as discussed) and, of particular significance, the recognition that the Universe appears to be 'fine-tuned' for life as we know it. It is simply too large a pill to swallow to believe that the only possible laws of physics, dimensionless constants and boundary conditions of a universe, in some metaphysical sense of necessary (for it is certainly logically possible that the Universe not contain life), are those needed for carbon-based life. The serious alternatives then seem to be divine design or a multiverse. Polkinghorne sees this as a welcome development,

> This proposal of a prodigious multiverse is not a scientific suggestion but a metaphysical speculation, a way to accommodate anthropic fine-tuning within a recklessly enlarged naturalism. It seems to me that a much more economic understanding is offered by the belief that there is only one universe, which is the way it is because it is indeed not 'any old world' but a creation that has been endowed by its Creator with just those finely tuned laws that have enabled it to have a fruitful history.[30]

In either case, those who conclude that reductionism has, in important ways, compounded rather than dissolved the mysteriousness of the natural world (leading many to adopt a Many-Worlds or God hypothesis as their terminus of explanation rather than a "simple physical principle" à la Weinberg) will be motivated to examine alternative strategies. However, suggestions of this sort can easily lead to anti-scientific positions, which we wish to avoid, and so it will be apt to tread carefully in formulating a useful approach to this subject area.

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[29] S. Weinberg, "Will We Have A Final Theory Of Everything?", *Time Magazine*, April 2000, accessed March 29th 2010, http://www.time.com/time/magazine/article/0,9171,996607,00.html

[30] J. C. Polkinghorne, *Science and the Trinity* (London: SPCK, 2004), 71.

2.2 Theological Arguments Discouraging Appeals To The Miraculous

Is the 'anthropic fine-tuning' then the final destination for any form of the argument from design - to place all the "teleology" in the initial act of creation? [31] Many theologians believe so, as Polkinghorne reports,

> Theology is a complement to science and not an alternative. Accordingly, contemporary natural theologians have turned from arguments about the outcomes of natural processes to the firmer ground that is provided by consideration of the laws of nature themselves. After all, those laws are science's given starting point, but it is conceivable that they are not so self-explanatory[32] that it is intellectually satisfying to regard them as brute fact. Cosmology and physics have now moved onto centre stage.[33]

Theology has thus withdrawn from the realm of biology and for sensible reasons. Firstly, appeals to irreducibility in biology and the need to invoke the supernatural will, likely, compound a sense of embarrassment that is perceived to have been wrought by positing a God of the Gaps in the past. Wishing to avoid any hindrance to progress, theologians have tried to steer clear of forebodings of the end of science and the need for divine intervention. In the eyes of many, the most famous blunder in this regard (besides Paley's perhaps) was Newton's 'solution' to the belief that the orbits are not gravitationally stable and thus required God's habitual intervention to set them right, a hypothesis Laplace famously declared superfluous in the court of Napoleon.

Secondly though is a deeper reason for this development in natural theology, one that stems from an analysis that positively concludes that God *prefers* to use natural processes, wherever possible, to bring about his unfolding purposes (I highlight "wherever possible" for reasons I shall return to later). If correct, this would create theological (not just scientific-methodological) disinclination to appeal to miraculous contraventions of physical law in one's account of the

[31] That is not to say of course that God must then be disconnected from the world - he is still involved in so far as he continually upholds it - only that the *design inference* is then off limits in some way.

[32] (The early) Wittgenstein would have said that they are not explanatory *at all* (see propositions 6.371-2 of the *Tractatus*). Of course, Polkinghorne recognises this dilemma and cautiously leaves the question open. "In all metaphysical discourse, there is always the question of how far one wishes to push the search for an intellectually satisfying explanatory basis. Is it enough to rest content with the brute fact of natural law or should one look further to an Agent whose steadfast will is taken to be the basis for the perceived regularities of nature and their fruitful consequences?" J. C. Polkinghorne, *Faith, Science and Understanding* (USA: Yale University Press, 2000), 92.

[33] Polkinghorne, *Faith, Science and Understanding*, 85.

natural world. How could this be? At first glance, it seems surprising that theism would disincline one to appeal to the miraculous. It is an counter-intuitive thesis to which Polkinghorne, who has spent a lifetime wrestling with paradoxical issues in the realm of quantum mechanics, has made valuable contributions.

His first line of thought comes about through contemplating the divine attributes in light of revelation. A principal quality of the Christian conception of God is his steadfast fidelity, a characteristic to be inferred from his creative expression.

> Divine upholding of the cosmos, whose regular laws are understood as reflections of God's unchanging faithfulness, is part of the story of God's relationship with the unfolding history of creation.[34]

Not only is this an expression of the Creator's character, but it is a necessary aid to our comprehension of the world. Consistency in natural process is required to make rational sense of one's environment; it is a *sine qua non* of meaningful intentionality carried out by creatures to be able to predict the outcomes of their actions.[35]

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[34] Polkinghorne, *Belief in God in an Age of Science*, 54.

[35] A parallel line of argument that has been somewhat neglected in such discussions could also be pursued by scientific realists: the world needs to have been consistent in its development over cosmic time to help ground a faithful epistemology of the external world. As Polkinghorne notes, "in terms of naked power, no doubt God could have created humankind fully fleshed, rather than allowing them to emerge after fifteen billion years of comics history, but he did not do so. That is the patient way that love works," Polkinghorne, *Science and Providence,* 65-6. Not only is this expressive of the Creator's kenotic love - allowing Creation the freedom to be itself - it is also viewed as a source of confidence that we are not part of some contrived puppet show akin to Descarte's worst case scenario. By *not* creating the world *ex nihilo* in some ready-to-go state (with adult creatures finding themselves fully-formed), God makes a world in which creatures can infer the past back to, in our case, a well defined physical system as given in the Big Bang scenario. The fact that the same physical laws we observe in operation today, operating on the early state of the Universe, lead to a Universe very much like the one we inhabit is a remarkable discovery of modern science. The correlation of prediction to observation and unification of initially disparate phenomena provide us with a startling sense of clarity, of the kind Descartes spoke, that helps ground a realist epistemology of the world. Suppose, by contrast, cosmic history were a complete mystery to us, that looking out into the sky there was only darkness. In such a case there would be no possible way to ascertain much (if anything) of cosmic origins, whether the earth had existed forever or had been conjured up in the recent past at the whim of a powerful agent. Such a world would lend itself much more readily to metaphysical scepticism amongst

The second line of thought as to why theists might want to think very deeply before invoking the miraculous is empirically motivated and concerns reconciling God's loving character with the fact of evil. The main problem seems to be an apparent capriciousness in so far as the Christian conception of God as Father, a being who is immanent in our lives and responsive to our everyday petitions, can permit evils on a global scale. To this end, Polkinghorne lays out his free-process defence:

> I think the only possible solution lies in a variation of the free-will defence, applied to the whole created world... In his great act of creation I believe that God allows the physical world to be itself, not in a Manichaean opposition to him, but in that independence which is Love's gift of freedom to the one beloved. The cosmos is given the opportunity to be itself.[36]

It is important to emphasise that, in Polkinghorne's view, God is not constrained by some external metaphysics, but it is in virtue of his own steadfast desire to endow creation with the freedom to be itself that results in his *causal* passiveness in the face of suffering. One must emphasise causal here since, at the same time, the Christian God is deeply present and affected in such circumstances, personally partaking in the suffering through the kenotic act of "becoming vulnerable" as reflected in Christ's passion and passivity.

> He is not a spectator but a fellow-sufferer, who has himself absorbed the full force of evil... The God revealed in the vulnerability of the incarnation and in the vulnerability of creation are one.[37]

For Polkinghorne then, divine inaction in a world of untold suffering is not an *ad hoc* supposition introduced to retain the coherence of theism, rather, it stands at the very core of the Christian faith. "The cross," says Polkinghorne, "is the fundamental basis of Christian theodicy."[38] It is thus

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its rational inhabitants, perhaps encouraging solipsism and discouraging concern for fellow agents. It is precisely because cosmic history is so coherent and intricately interwoven with other domains of human knowledge that the human psyche is impelled towards the dismissal of Boltzmann Brains and other sceptical scenarios thus encouraging a realist (and empathetic) view of the world. As Polkinghorne puts it, "so marvellously patterned is that experience that I, for one, cannot doubt that it is the discernment of an actual reality," J. C. Polkinghorne, *Science and Creation* (USA: Templeton Foundation Press Edition, 2006), 85.

[36] Polkinghorne, *Science and Providence*, 66.

[37] Polkinghorne, *Science and Providence*, 68.

[38] Polkinghorne, *Science and Providence*, 68.

Polkinghorne's deep reflection on the problem of evil that leads him to conclude how very much God must be constrained by his *own* nature.

> [T]his kenotic sharing of power has important implications for theodicy. No longer can God be held to be totally and directly responsible for all that happens... this is a self-qualification, exercised within the divine nature and in accordance with that nature itself... The classical theologians... had not taken adequately into account the interior 'constraints' of the self-consistency of the divine nature."[39]

The classical theologians did have a genuine concern - this theodicy risks leaving no room for God to play an authentic role within the creative order. Is God so constrained by his nature so as to be *causally* indistinguishable from deism? This is a perplexing problem that Polkinghorne approaches from many different perspectives seeking to reconcile the steadfast character of natural law, free will and divine action; each perspective offering a complementary "glimmer of how it might be that we execute our willed intentions and how God exercises providential interaction with Creation."[40]

One such glimmer is Polkinghorne's notion of "active information" motivated by, amongst other things, the pilot-wave theory of Bohmian mechanics.[41] Others come from insights afforded by chaos theory and quantum indeterminacy which create an epistemological openness to the world that, he contends, imply an ontological openness in which God's "active information" can effectuate without violating natural law.[42] At the same time, Polkinghorne recognises that while the intriguing aspects of chaos, quantum mechanics and information theory allow a certain "room to manoeuvre" with respect to free will and divine action, they cannot be stretched to accommodate all traditional claims of God's interaction with the world. In particular they cannot account for the doctrine of the resurrection, which Polkinghorne takes to have been physically prefigured in Christ.[43] He thus concours that, "in unprecedented circumstances, it is entirely conceivable that God will act in totally novel and unexpected ways"[44] while carefully avoiding

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[39] J. C. Polkinghorne, *The Work of Love* (USA: Eerdmans Publishing Company, 2001), 95-6.
[40] Polkinghorne, *Belief in God in an Age of Science*, 62-3.
[41] A well-known deterministic interpretation of Quantum Mechanics.
[42] That is, bringing about an intended state of affairs without, say, violating energy conservation.
[43] "Also important, I believe, is the witness of the empty tomb, for the fact that the Lord's glorified body is the transmuted form of his dead body speaks to me that in Christ there is a destiny not for humanity only, but also for matter, and so for creation as a whole," Polkinghorne, *Science and the Trinity*, 86.
[44] Polkinghorne, *Belief in God in an Age of Science*, 73.

the claim that God "intervenes" in such cases. How one is to make sense of the miraculous without 'intervention' is the subject of the next section.

2.3 Recasting The Miraculous

So far, we have seen theological reason (distinct from, say, scientific reason) to think very deeply before appealing to divine intervention as God prefers, in some general sense, to achieve his purposes through natural process. This flows from his nature as a kenotic creator desiring to furnish creation with a genuine autonomy of its own. Yet, that same nature also allows for this *apparent* laisser-faire policy be overridden in "unprecedented circumstances" where physical law, as it is usually conceived, is incapable of accomplishing some other, more important aspect of the Creator's will. For Polkinghorne, the resurrection is just such a case. His work implies that, although God desires the physical world to operate in a predictable (and therefore transparently consistent) manner for the sake of his creatures, the revelatory significance of the physical resurrection of Christ is more desirous still.

The two are not compatible. If one asks, 'why didn't God use physical processes to bring about the resurrection? ' the answer is simple: it is not *possible* given the usual laws of physics. In some sense of course God doesn't have to use 'physical' processes at all - he is free to act as his will calls for - but it is impossible for him to *both* adhere strictly to the laws of physics (as they are currently conceived) *and* to bring about the resurrection (or other 'extraordinary' events) at the same time.

Presumably then, if God could have used natural processes to bring about the resurrection, he would have,[45] but in such a case where his purposes require the execution of the physically impossible, the 'extraordinary' can be expected.

There therefore arises an implicit ordering of priorities within the divine will that is reflected in the world: for the sake of an autonomous and rationally intelligible creation, transparently consistent and open natural processes are the rule; for the sake of revelation in the case of "unprecedented circumstances," miracles are the *apparent* exception.

I say apparent because, according to Polkinghorne, "God must be utterly consistent in his relationship with the world, but consistency does not mean a dreary uniformity."[46] In other words, although miracles are rare in his opinion, they still follow the same 'expanded' (constantly valid)

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[45] That is unless, of course, it is entirely *because* of its physical impossibility that God brings about the resurrection. If the sole purpose is to demonstrate his power over nature in an indisputable manner, then God would have to contravene the normal course of nature. But as Polkinghorne says, "God could not be whimsically capricious about deciding to do something unprecedented, as if engaging in an act of divine showing off," Polkinghorne, *The Work of Love*, 105.

[46] J. C. Polkinghorne, "God's Action In The World", CTNS BULLETIN, Vol. 10, No. 2, Spring 1990, accessed 29th March 2010, http://www.polkinghorne.net/action.html

principles that can span, not just the space of physical states, but the spiritual and moral as well. He explains,

> I am carefully trying to characterise the event as 'unexpected' rather than using discontinuous language like 'due to direct divine intervention'... My reason is simply that I believe that God's complete action in the world must be consistent throughout. In the end there is no sharp separation to be made between general providence and special providence and miracle.[47]

How then are we to understand the transition, or the 'switching', between the 'general' and the 'special.' To explain this, Polkinghorne uses the analogy of a phase change in physics (as in heated water turning to steam at boiling point) where the underlying law remains the same but a new regime is entered that acts in "totally unprecedented, totally unexpected consequences." George Ellis puts this idea into a more concrete example when he speculates,

> [There is the possibility of the] existence of a new order, a new regime of behavior of matter (cf. a phase transition), where apparently different rules apply... [W]hen the right "spiritual" conditions are fulfilled... the extraordinary would be incorporated within the regular behavior of matter, and neither the violation of the rights of matter nor the overriding of the chosen laws of nature would occur. Thus the laws of physics are respected. The charge of capriciousness would then fall away... This is related to collapsing the distinction between the natural and the supernatural, from God's point of view. An example could be Jesus' resurrection.[48]

If Polkinghorne is correct, this would essentially mean that the operation of matter is ultimately more *complicated* than how it is usually conceived in science, especially if the operation of matter were to depend on the mental or spiritual state of the environment (if indeed these can be distinguished from the physical state in some ontological manner). As noted earlier, the appearance of miracles can always be represented by an increase in the complexity of the world which can itself be connected (via the analogy of the cosmic computer) to the implementation of an if-statement in the structure of reality: **if** certain conditions are met, **then** a new regime is entered.

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[47] Polkinghorne, *Science and Providence*, 50.

[48] G. F. R. Ellis, "Ordinary And Extraordinary Divine Action", in *Chaos and complexity: scientific perspectives on divine action*, ed. R. J. Russell, N. Murphy and A. R. Peacocke (California: Vatican Observatory Publications & Berkeley, 2000), 386.

Mathematically, this could make the physical representation of the Universe tremendously more complicated, perhaps with the inclusion of an infinite number of extra terms in the equations of motion. But as indicated earlier, a well-executed if-statement can do the work of an infinite number of mathematical operations. So while the apparent arbitrariness of (reported) occurrences of miracles arises because the mathematically equivalent representation of their enactment would be too complex to allow the discernment of any pattern, the underlying reason could depend on a comparatively simple explanation if one is willing to allow for a richer ontology than that which defines reductive materialism.

We then have a conceptual framework to help understand how top-down causality (the sort we wish to affirm for the 1st-person perspective of human agency) and the 'extraordinary' emerge from a world that would otherwise appear to be reducible to particles in motion. God relates to these processes in so far as he has established and continually upholds the Universe as well as authoring the 'cosmic code' that relates one temporal slice of the world to the next. This abstract code organises but does not (necessarily) determine the bounds of possibility. An analogous example would be a program that traces out a chaotic trajectory with inputs from a random number generator; although the exact output on the screen cannot be determined in detail, the algorithm constrains the results from being meaningless noise.

Moreover, when particular conditions are seen to have been met within the program (at either the macro or microscopic scale), a phase transition can be implemented in the code via an if-statement. This can help make sense of the interplay between top-down and bottom-up causality that Polkinghorne has in mind when he writes,

> If one adopts the admirable stance of asserting that wholes are more than mere sums of their parts, and combines this with the concept of a relatively orderly world, one is implicitly suggesting that there are holistic as well as constituent laws of nature. The structured richness of reality then results from an interplay between these two kinds of laws, and there is the problem of how we should best think about their mutual interrelation.[49]

The example to follow is rather crude (pressing it for detail would require an essay in itself) but helps illustrate the basic idea of how such "interrelations" might be implemented in the 'cosmic code' of the Universe via 'collapse of the wave-function':

[49] J. C. Polkinghorne, "The Laws of Nature and the Laws of Physics", in *Quantum Cosmology And The Laws Of Nature*, edited by R. J. Russell, N. Murphy and C. J. Isham (California: Vatican Observatory Publications & Berkeley, 1996), 430.

if *macroscopic* agent[50] has intention X **and** certain physical conditions are met **then** realise *microscopic* state such that X results

else realise *microscopic* state according to the Schrödinger equation (or some other causal procedure)

Three comments will be useful here. Firstly, scientists are so accustomed to thinking that nature only deals with expressions like the individual terms in Eq. 2 (i.e. smooth and differentiable functions) that it takes some getting used to before discontinuous functions, as given by an if-statement in Eq. 1, cease to feel 'unnatural.' This is probably because if-statements produce non-linear complexity[51] that one does not expect in fundamental laws given the way reductionistic science is presently conceived. Also, needless to say, it is well outside the paradigm of modern scientific methodology to suppose that top-down or holistic causality is part of the structure of reality (with some research programs into quantum mechanics being the exception). This calls for a degree of open-mindedness in the manner advocated by Polkinghorne.

> Physics is taking a holistic turn. The possibility of the existence of holistic laws of nature is one which should not be discounted. Certainly such laws would be more difficult to discover than the familiar laws governing the behaviour of parts, and their form would surely be different from that of the differential equations which are the staple of current localized mathematical physics. Yet it would be a Procrustean imposition on science to deny that it could have access to such laws.[52]

Secondly, it may appear at first from the code in the above example as though 'holistic' causes in some way trump the 'constituent' causes by taking precedence in the if-statement. This is until we remember that the microscopic gives rise to the macroscopic in the first place. There is therefore the potential for a rich feedback structure whereby constituent causes give rise to macroscopic structures that then 'switch on' new modes of causality that feed back into the microscopic. In this case, a totally consistent law, applicable throughout all space and time, would control the "mutual interrelation" between the 'holistic' and 'constituent' causal modes of nature.

Thirdly, some might object that causality in this scheme seems too artificial and, therefore, too much like occasionalism - the idea that God straightforwardly determines the motion of matter in sync with, and on behalf of, the choices we make in some disconnected 'mind space.' In

[50] One might want to replace 'agent' here with 'configuration of matter corresponding to an agent' on Polkinghorne's dual-aspect monism.
[51] Or, equivalently, an infinite number of linear terms.
[52] Polkinghorne, "The Metaphysics Of Divine Action", 150.

such a view the real 'us' is the dislocated mental substance and it becomes questionable whether one really needs a physical world at all. However, as stated earlier, the conceptual scheme at hand is metaphysically neutral. It is consistent with occasionalism in so far as such a puppet universe can be represented using the conceptual scheme laid out in §**Error! Reference source not found.**. Ultimately though, the cosmic-code representation merely describes the *form* of causal relationships in the real world without dictating their ontology.[53]

The scheme is therefore just as compatible with the open and temporal-becoming of Polkinghorne's critical realism. However, if one wishes to drape Polkinghorne's ontology explicitly over the proposed conceptual scheme, one will find they link very naturally. In such case, God continually upholds the world according to consistent laws (analogous to computer code) that describe the evolution of the Universe from one moment to the next in an open (i.e. involving a random number generator) but bounded manner. With each passing moment, the Universe is neither completely random nor determined, but is bounded by the state in the previous moment. God's grasp of the future comes from "seeing" every detail on the cosmic screen and understanding the possibilities allowed by the code he has decreed. With this knowledge at hand, God is able to respond and act in the world in a similar way to a programmer at the keyboard, not by capriciously rewriting the code at any moment or magically altering the contents of the hard drive, but by feeding "active-information" into the openness inherent in the program. Finally, the structure of the code is such as to interrelate the holistic and elementary through if-statements that switch between different regimes of behaviour. This mutual interrelation between the macro and the micro, the top-down and bottom-up, makes sensible the claim that "there is no sense in which subatomic particles are to be graded as "more real" than, say, a bacterial cell or a human person."[54] In such a world, there is proper freedom[55] and non-reducible emergence of the kind envisioned by Polkinghorne when he writes

> The everyday world is constructed of constituents from the quantum world but, as these entities combine together into systems of greater and greater complexity, new possibilities come into being, exhibiting properties (such as life and consciousness) that were unforeseeable in terms of the simpler constituents out of which they are made, while only realizable through the potentialities with which those same entities are endowed. Thus, the growth in organization produces genuine novelty, and each level (biological, human, social) enjoys its own autonomy in terms of concepts that are not simply reducible to those associated with lower levels.[56]

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[53] Those who are rather Humean in their stance on causality (as is the author) will not be too bothered by this objection.
[54] Peacocke, quoted by Polkinghorne, *Science and Providence*, 29.
[55] Assuming of course that libertarian freedom is truly possible.
[56] Polkinghorne, *Science and Creation*, 46.

To summarise so far, Polkinghorne gives us strong theological reason to suppose that the Universe is implanted with a deeper structure than normally supposed by reductionist science, a structure that takes the form of completely new regimes of physics that are activated if non-physical (in the usual sense of the word) conditions are met. Although I do not claim to have definitively solved the puzzles as to how God acts in the world, the proposed conceptual scheme allows us to view the subject from the relatively untapped and, I believe, illuminating perspective of a programmer-computer relationship. Hopefully it can come to stand alongside and complement other ways that theologians have tried to express the nature of agency - both human and divine - in a world of unwavering natural law.

In the next section I shall return in more detail to the possibility that a related though more 'physical' type of if-statement[57] is implanted into physics and that anthropic reasoning, which has become mainstream in cosmology, offers reason to take this possibility seriously. Such if-statements might 'switch on' new phenomena at higher-levels of biological process, perhaps in the regime of DNA structure, that would prove *immensely complicated* to represent in the usual reductionist scheme of biochemistry. Nonetheless, such processes would be entirely physical in so far as their operation would occur consistently throughout all space and time.

3 Scientific Motivation For Cosmic If-Statements

3.1 The Limits Of Physical Intuition

In view of this discussion, what then are we to make of the sense of the "unexpected" in the "bias" of matter that Montefiore was trying to communicate? Does it merely reflect our ignorance of the intricacies of matter and physical law? Not necessarily. We are never totally ignorant about what matter, operating under (our current conceptions of) physical law, can and cannot do. Indeed, the very structure of physical law is designed to demarcate what is and is not possible.

In fact, it is very easy to cite extreme examples of counterfactual phenomena that would call physical reductionism into question. In particular, we all have some sense of what evolution can and cannot produce, though there is great dispute over the details of the divide owing to the complexity of such systems. As Dennett illustrates,

> One may... be reasonably nervous about the size of the role of sheer, unfettered imagination in adaptationist thinking [in evolution]. What about butterflies with tiny

[57] That is, if-statements that don't depend on moral or spiritual conditions, but strictly physical in the usual scientific sense.

> machine guns for self-protection? This fantastic example is often cited as the sort of option that can be dismissed without detailed analysis... It is just too distant a possibility in design space to be taken seriously. But as Richard Lewontin aptly notes, "My guess is that if fungus-gardening ants had never been seen, the suggestion that this was a reasonable possibility for ant evolution would have been regarded as silly."[58]

The point Dennett makes here is that, though we have *some* intuition about the capacities of matter in complex systems, it is extremely difficult to know in any detail how far these intuitions can carry us. If we then set aside any allegiance to reductionism as a methodology, and ask to what extent we actually *know* that biological processes are straightforwardly reducible to fundamental physics, we find that our intuitions tell us rather little (or, that intuitions on the matter vary radically from one individual to the next).

By straightforwardly reducible I mean, for example, that all energy levels in biochemical processes are in principle calculable by solving the Schrödinger equation using the established constituents of atoms (electrons, protons and neutrons). If an energy level were found that were not reducible in this way then the reductionist would have to add extra terms to the potential corresponding to new modes of energy propagation (i.e. we'd have to posit new 'stuff' and/or new properties that complicate the way particles couple with each other in the evolution of the system). Of course, it would be tremendously difficult to find such an energy level because of the problem of underdetermination - is the apparent discrepancy due to an error in the experiment, inaccuracy in the *ab initio* calculation[59] or because our physics is genuinely incomplete and therefore requires expansion?

It is easy to understand from the practical point of view why it is that scientists would strongly resist adjusting fundamental theory in this way. This is usually a last-resort since their goal is to represent the processes of nature in as simple a form as possible and adjusting the equations almost always complicates them. But as argued in §**Error! Reference source not found.**, the desire for ultimate simplicity is a pragmatic idealisation that must eventually run up against the minimal degree of complexity in our Universe required by the Anthropic Principle. The assumption that the world is ultimately simple at its core is not a promise that nature has made to us. Though humankind can rightly take pride in its collective discoveries given our many limitations, it is important to keep our capabilities in perspective. We are only able to write down those aspects of the Universe that are isolable and tractable and so it would be naive to suppose that we have already exhausted all the major surprises that nature has kept hidden. As William Stoeger explains,

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[58] D. C. Dennett, *Darwin's Dangerous Idea* (England: Penguin Books, 1996), 251.

[59] That is, solving the fundamental laws of physics bottom-up with little or no short-cuts or approximations.

> [The physical] phenomena, and therefore the theories and laws [that govern them], are not able to reveal all features of observed reality nor even its most fundamental features. Some of them are hidden from, or inaccessible to, our probing. This is simply because, in making our observations and measurements, we focus on those stable and characteristic features [of which] we are capable... But there may be, and certainly are, many aspects of observed reality which are neglected or simply missed... Certain parts of reality in which we are immersed are such that we can successfully model them in all their detail - they are algorithmically compressible. But that fortunate and mysterious trait of reality should not delude us into thinking that we have a direct access to reality as it is in itself - if indeed this term has meaning.[60]

The fact is, no one has an intimate enough knowledge of particle physics and the way it combines into chemistry and biochemistry to really know if the "bias" in matter is something that is reducible to fundamental physics (as it is conceived today) without having to greatly complicate the equations such that, for example, effects come into play at larger (e.g. biological) scales that are negligible at lower (e.g. atomic) scales. Moreover, as Eugene Wigner pointed out, such 'hidden terms' are only likely to be found if one is already looking for them.

> The possibility that we overlook the influence of biotonic phenomena, as one immersed in the study of the laws of macroscopic mechanics could have overlooked the influence of light on his macroscopic bodies, is real.[61]

However undesirable it might be to complicate the equations of physics, it might ultimately prove necessary.[62] At the same time, it remains the case that we just don't know whether such bio-friendly regularities observed at the macroscopic are, in fact, straightforwardly reducible to fundamental physics (as it's presently conceived). In the face of such difficult questions, Polkinghorne is quite right to discourage the equation of our ignorance of the facts with God's intervention. Montefiore went on to equate the "bias" in matter with the "work of the Holy Spirit." Polkinghorne responds:

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[60] Stoeger W. R., "Contemporary Physics/Laws Of Nature", in *Quantum Cosmology And The Laws Of Nature*, edited by R. J. Russell, N. Murphy and C. J. Isham (California: Vatican Observatory Publications & Berkeley, 1996), 220-1.

[61] E. Wigner, quoted by P. C. Davies, *The Cosmic Blueprint* (USA: Templeton Foundation Press, 1988), 148.

[62] A good example of this sort of problem is the debate over Dark Matter - does Newtonian physics enter a new regime of behaviour above a certain scale (requiring an adjustment to the equations), or the positing of a new and exotic form of invisible matter? I.e. do we complicate the equations or add to the length of the state-vector (or both)?

The question of whether such effects are present [in biology] is a scientifically posable question and I see no reason why it should not be expected to receive a scientifically state-able answer. There may be more to evolution than has met the neo-Darwinian eye, but to call that missing ingredient in our understanding the Holy Spirit is to invoke the God of the Gaps.[63]

This is a common 'blunder' that Polkinghorne is sharp to denounce; the suggestion, that anything that at first seems physically intractable is indicative of divine intervention, leads, almost invariably, to a God of the Gaps that will one day prove superfluous (and even if it doesn't, it's not scientifically *useful*).[64] Polkinghorne urges that God's interaction is not one of *intervention* since God must act in a totally consistent manner. "The true God is related to the whole of creation, not just the puzzling bits of it."[65]

3.2 A Practical Approach

The more scientifically useful and theologically informed question that Polkinghorne would wish to pose is not, therefore, whether God is 'intervening' in the course of biological processes, rather, Polkinghorne would prefer the more neutral question of whether 'biotonic laws' are to be found in nature. I wish to suggest that the most promising form of such a law would be that of an 'if-statement' (or their equivalent representation in the form of hidden terms whose effects become non-negligible, that is, 'switch on' under certain finely-tuned conditions) whose effect is to encode a degree of non-linear complexity that might be required for biology and evolution to take place.

It is a metaphysically neutral proposal because, if such if-statements are *anthropically* required, then they can be explained by the standard paradigms for the 'fine tuning of the Universe for intelligent life', namely, by divine design or a selection effect from a Multiverse realising a wide variety of logically possible and physically distinct domains.[66]

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[63] Polkinghorne, *Science and Creation*, 70.

[64] The relationship between scientific realism and human utility ('usefulness') is an important subject that deserves more attention than is possible here. It is worth noting in passing that Polkinghorne places a great deal of epistemic weight on the 'usefulness' of ideas - "There is no logically inevitable way to proceed from epistemology to ontology... It can be resolved only by an act of metaphysical decision... by an appeal to the fruitful success of the strategy adopted," Polkinghorne, *Belief in God in an Age of Science*, 53.

[65] Polkinghorne, "The Laws of Nature and the Laws of Physics", 438.

[66] See J. Leslie, *Universes*, for an excellent discussion of these interpretations of the Fine Tuning.

In the prior case, such if-statements would arise from the Creator's consistent, law-like intention to uphold the world in a manner habitable by (in our case) carbon-based life forms. Such if-statements, if they exist, implant matter with the bias to which Montefiore alludes, and hold-true for all space and time in keeping with the Creator's consistent intention to make the Universe as open to inductive reasoning as possible. In that manner, they are distinct from the classical notion of a miracle as some sort of occasional and spatially-localised contravention of physical law. These if-statements complicate the laws of physics, which is undesirable in and of itself, but are nonetheless necessary to achieve the functionality of biochemistry.

In the latter interpretation of biotonic if-statements, using the Multiverse, if it is the case that they are necessary for life as we know it to evolve and persist, then only universes that have them will have 'physical observers' to note their occurrence. In such a case all universes where physics *is* reducible to the Schrödinger equation as we presently envisage it (without any hidden terms or if-statements that 'switch on' in higher-level processes) would be sterile. That is, they would not be complex enough to furnish biochemistry. One would have to move to a different (presumably smaller)[67] subset of more complicated universes to find life. However rare such universes might be though, in a sufficiently large and diverse Multiverse, they will be bound to occur.[68]

So far I have discussed the conceptual possibility of 'regime switching' in the laws of physics controlled by virtual if-statements and suggested theological and scientific motivation to take the notion seriously. The scheme fits well with Polkinghorne's theological reflections as to the steadfast character of the Christian God and his philosophical-scientific thoughts regarding emergence and openness in the physical world. He writes,

> I have considerable sympathy with the belief that the fruitfulness of cosmic and terrestrial history is such that it is reasonable to seek to supplement current received evolutionary ideas with the operation of possible teleological laws of nature... Darwinian ideas provide partial insight into the developing history of a fruitful world but it is certainly not known that they tell the whole story.[69]

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[67] This brings up the 'measurement problem' with respect to Multiverses; how does one measure the relative frequency of one type of universe to another in the Multiverse and thus determine whether or not universes like ours are 'rare' in the Multiverse. It is the hope of Multiverse proponents that a physically motivated model of the Multiverse (as the 'String Landscape' is alleged to be) would turn out to predict that universes like ours are relatively common. This whole field is, however, fraught with difficulties of comparing infinities with infinities as well as putting substance into phrases like "physically motivated" and what it means to be an 'observer.' (see Darg 2011.)

[68] This is especially true of the variety of Multiverse reflecting the philosophical position of modal realism where, crudely speaking, 'everything that can exist, exists.' C. f. David Lewis and Max Tegmark.

[69] Polkinghorne, *Beyond Science*, 78-9.

One might complain though that no *positive* argument has been given yet to think that physical if-statements are in fact needed for biology to function as it does. This relates to the difficult connection between epistemic possibility and actual possibility[70] and, given the complexity of the systems in question, must therefore come down to a judgement according to the individual's overall grasp of the physical situation in question. The purpose of the next section is to encourage contemplation of just how easily the constraints of 'fundamental law' could frustrate the bottom-up construction of biological functioning.

3.3 The Perils Of 'Monkeying With Physics'

Consider a crude thought experiment. Suppose you are to design a Universe containing matter to be governed by natural law where, as a rule of thumb, you must make the laws as simple as possible whilst allowing for the emergence of intelligent life in the course of time. Suppose you begin with a simple system like a Hot Big Bang with gaussian inhomogeneities that, under a simple law of attraction ($1/r^2$), will condense into structures. You find that, with only three other forces and some simple rules (quantum mechanics) exhibited by a modest number of fundamental particles, you are able to produce stars from these gravitational structures which allows these particles to combine into heavy elements in their hot interiors. These stars explode in due course and scatter the elements into the interstellar medium available to re-condense into a proto-solar system. A chemically rich planet thus forms and oceans gather on its surface.

The water in these oceans proves to be a versatile solvent for atoms to begin to interact in accordance with their electron shells that are determined by the same laws of quantum mechanics that brought about their formation in the core of the stars. This leads to a crude form of chemical reproduction that progresses onto a self-replicating cell. Unfortunately, a problem then arises - a vital chemical reaction needed for larger self-replicating organisms doesn't quite work - an important energy level of catalyst X is a fraction of an electron volt (α eV) too small to bind and speed up an important protein folding. You try solving the problem by tweaking the fine-structure constant. That raises the energy level to the right amount but now, another energy level in a different reaction is too large. You try to solve this by increasing the mass of the proton by a tiny-fraction; but now nucleosynthesis in stars occurs at one tenth its previous rate, so stars need to burn longer to get enough elements. And so on. After exhaustive efforts you find that any attempt to fix a problem by changing the fundamental laws of physics ends up disrupting things elsewhere

[70] Consider a deeply technical mathematical proposition that is, as yet, unproven. We would be able to say, in so far as we are ignorant of the truth value of the proposition, that it is possibly true (i.e. it is epistemically possible). Suppose then that someone comes up with a disproof that gains acceptance by the mathematical community. We would then no longer say that the proposition is possibly true but, rather, that it is necessarily false.

- the systems have become too complex and there are simply too many constraints welling up from the coincidences that you've already taken advantage of in basic physics. What you end up finding is that it is simply not *logically* possible for you to *both* use the physical laws so far established consistently across all space and time *and* bring it about that life will evolve by itself without further, specific acts of contravening the laws so-far decreed.[71] In this case, do you

(A) Abandon the whole plan (or start all over from scratch)

(B) Make the laws more complicated so that only *in this regime of physics* the necessary effect is actualized

Although this thought experiment is highly simplistic, the fact that many of us would choose option B might make us sympathetic to the possibility of such 'regime changes' in the laws of nature. If a human programmer were tackling the above problem, the solution would be to simply implement an if-statement into the cosmic code: **if** configuration X obtains, **then** adjust the energy level by α eV.

Three comments are apt at this point. Firstly, those of a scientific orientation might be highly concerned that some deeply held principle of physics will not allow this (as though such principles are in some way inviolable). In this example, energy conservation would be broken. I don't believe this is a serious problem at all. Maybe the Universe makes consistent exceptions - if Bohmian mechanics (a respected though seldom embraced interpretation of quantum mechanics) is true then particles do not travel inertially either. Moreover, it would be very easy to balance out the energy, for example, by increasing or decreasing the rest-mass of the molecule by the corresponding energy difference or absorbing/emitting a photon.

Secondly, the idea that God is constrained as to how the Universe operates (as portrayed in the above thought experiment) comes right out of theodicy. If God were to adjust physical law so that earthquakes never happen then this would produce massive ripple effects throughout the natural world that would almost certainly make life impossible for one reason or another. As Polkinghorne states, "the existence of tectonic plates allows mineral resources to well up in the gaps between them, thereby replenishing the surface of the earth, but it also allows earthquakes and tsunamis to occur. You cannot have one without the other."[72]

Thirdly, if one were to choose B in the above thought experiment, and if one were therefore willing to allow that God *might* use a single if-statement to solve a biochemical engineering problem vital to life, why stop there? Perhaps biology is so complicated at the cellular level that if-statements of this sort are required all over the place. It was, of course, the complexity of the

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[71] And I assume of course that not even God can do the *logically* impossible.

[72] J. C. Polkinghorne and N. Beale, *Questions of Truth* (Louisville: Westminster John Knox Press, 2009), 65.

cell that urged Elsasser, the father of systems biology, to posit the conceptual category of biotonic processes in the first place. It is difficult to observe the working of a cell and believe that all of this movement is essentially reducible to 'lego blocks' in motion simply bouncing off each other seeking thermodynamic equilibrium.[73]

Where would one look for such if-statements then if they had the resources and motivation? The best choice would be biochemistry. This is the regime where complexity takes off like no other place in the Universe and is therefore the most likely regime where if-statements might be anthropically required. Also, chemistry provides a very 'neat' place to encode 'phase changes' since bonds and energy levels are quantized. The conditions that the if-statements would act on would then be questions of whether a configuration is in place and whether any adjustments need to be made. More detailed areas of investigation are suggested in the Appendix.

4 A Challenge To Intelligent Design

Politics and 'wedge strategies' aside, I wish to focus briefly on some of the philosophical questions that the ID movement has prompted within theological and scientific circles. In *Darwin's Black Box*, Michael Behe goes to great lengths to describe the intricacy of biochemical processes. The grandeur of such microscopic architecture sets the stage for his argument based upon 'irreducible complexity' - an argument so well-known now that it needs no repetition here. This leads to the proposition of 'intelligent design' which many have read as (ultimately) an appeal to direct divine action of the creationist variety.

How well does Behe's (implied) interventionism cohere with his affirmation of common decent? This is difficult to assess owing to the reticence of ID proponents to posit a mechanism by which the Agent 'designs' the system. In any case, the proposal has a strong anti-uniformitarian flavour to it suggesting that highly non-linear events took place in the past (the sort that we associate with actions carried out by intentional agents such as ourselves) that are no longer directly discernible since they are not embedded in the natural structure of the world. Such discontinuities are distressing to scientists (who, as discussed already, depend on Nature operating 'smoothly') and stand in contrast to what Polkinghorne describes as the "gentle providential guidance exercised within the openness of natural process, of the kind 'theistic evolutionists' tend to favour."[74] In short then, there are two problems. Firstly, there is the theological problem that we have already discussed stemming from the problem of evil to Polkinghorne's thesis: God does not rewrite his code when (and as if) things fail to go to plan. Rather, he is consistent from start to finish, capable of foreseeing technical obstacles like

[73] I highly recommend the reader watch the animation of the cell in the given link in order to fully appreciate the sense of non-reducibility, to which Montefiore alluded, being expressed here: http://www-astro.physics.ox.ac.uk/~ddarg/shtml/cell_animation.shtml

[74] Polkinghorne, *Faith, Science and Understanding*, 93.

‘irreducible complexity’ and, therefore, capable of writing the laws of nature with sufficient complexity to overcome them. It is then the *empirically motivated* doctrine that God gives the world the freedom to ‘create itself’ that increases one’s expectation that nature does have the requisite complexity built into its laws to accomplish this (so that these effects would still be accessible to science today). Polkinghorne summarises the thought as follows

> God is never spoken of as a “designer” in the Bible: he is Creator and Father, and a Father does not “design” his children... By endowing us with free will and giving us the capacity to love, God calls us to be in a limited but very important sense co-creators.[75]

The second problem is more practical. I am personally sympathetic (as is Polkinghorne - see quotations of his works in §2.3 and §3.2) to the claim that a degree of non-linear complexity might be required in biological processes that is not provided by the (relatively) simple physical laws that have been ascertained so far by reductionistic science. But if these ‘complexities’ were instantiated exclusively in the past by some supernatural intervener, and which are therefore inaccessible to science in the present, then it is difficult to see how any useful research program can result from this proposal.[76] This, many claim, disqualifies it from bearing the premium of ‘science’ as it does not comply with the (pragmatic) methodology of reductionism.

Moreover, it is very difficult to see how Darwin’s challenge[77] could ever be falsified beyond doubt since one can *always* appeal to the future hope that new discoveries will lead to new and unexpected discoveries to solve problems that currently seem intractable.

A more useful and more ideologically neutral program would result by taking the theological arguments of Polkinghorne seriously and re-orientating such research around the pursuit of biotonic laws - laws that emerge in higher level processes that are not reducible to physics as it is currently conceived. If one were able to find such ‘if-statements’ and thereby falsify current assumptions, biology and physics would be revolutionised. If none are found, then the sociological effect would no doubt serve to strengthen the *status quo* of reductionism à la Popper, but at least we’ve learnt something new about nature and, from the theistic perspective, shown that God simply didn’t need to intervene over and above the laws he has set in place.

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[75] Polkinghorne and Beale, *Questions of Truth*, 57.

[76] Again, the deep and perplexing question arises concerning the role of utility in science - a question that can not be dealt with here except to point out that the two are intimately connected.

[77] “If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down,” C. R. Darwin, *The Origin of Species* (New York: Oxford University Press, 1998), 154.

I do not wish to speak casually of the difficulties - conceptual and practical - that one would have to undertake in accepting such a challenge: scientific research demands tremendous resources and commitment. It also requires support from the human *community* which the ID movement has made difficult for itself by being so forth-right with its ideological agenda. This is a shame for those of us who, joined together as a philosophical community, wish to learn about those parts of the world that are most central to our origins and existence. Polkinghorne's work suggests both theological and scientific motivation to search for such biotonic phenomena in the structure of the world but, unfortunately, it is unlikely they will ever be sought so long as ideological struggles preclude such research programs ever being taken seriously by the scientific community.

Summary

The conceptual scheme that compares the Universe to the operation of a computer operating according to a set of rules, that I have referred to as 'cosmic code', is a helpful analogy for God's relation to the world. In order to accommodate life, this code requires a minimal degree of complexity. A key concept in programming complexity into computer code is the use of an if-statement that switches between regimes of behaviour.

In this representation, miracles are the *complications* rather than the *contraventions* of natural law. Given that a minimal degree of complexity is required by the anthropic principle one is confronted with the question whether this complexity is most efficiently represented with the occurrence of if-statements in nature. This proposal is compatible with both a theistic-design or Multiverse-selection-effect scenario. Given the astounding complexity observed in biological processes, there is no (non-practical) reason to suppose *a priori* that such if-statements are not required and that all life processes are straightforwardly reducible to the Schrödinger equation in action.

This conceptual scheme lends powerfully to the important theological contributions Polkinghorne has made. According to him, the Christian conception of God is that of a steadfast and consistent sustainer of the world who does not capriciously contravene the functioning of the Universe. The world is truly allowed to be itself within the bounds of natural law prescribed by the Creator. At the same time, Polkinghorne sees the structure of reality as being much richer than reductionist science would imply; nature is orchestrated such that top-down causality and 'the extraordinary' emerge in an irreducible manner from the bottom-up causes that constitute the world. The notion of if-statements in the cosmic code assists us in conceptualising how such transitions might take place within the consistent laws of nature that God has 'programmed.' Moreover, God can interact with creation as a programmer does during the operation of the computer, not by arbitrarily re-writing the code, but by feeding what Polkinghorne would call "active-information" into the openness that was built in from the start.

Finally, I suggested some practical ideas about where one might look for such hidden structures. This is a more practical program than those that have gone before it, namely, in search of 'irreducible complexity.' It would be a tremendous accomplishment if Polkinghorne's theological reflections lead to the discovery of scientifically describable structures that the theist would wish to interpret as the hallmarks of the Creator in a Universe given freedom to co-create itself.

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Appendix: Water

Few appreciate just how difficult it is to solve the Schrödinger equation even for very simple systems. The Hydrogen atom (one proton and one electron) is basically the one system that can be solved 'exactly.' Beyond that, one must employ approximations to greatly simplify the problem. By time one gets to proteins (with hundreds of protons, electrons and neutrons), the calculations are far removed from the *ab initio* ideal.

To illustrate the difficulties that beset this field, I shall say a word on water. Despite it being the most important liquid for life and thus the subject of much research, its structure and properties are still not fully understood. Water has several peculiar properties that make it vital for life such as it's increased density in liquid state,[78] its high melting point, etc.

Several of these properties arise due to its bond angle (~104.5°) being close to that of a perfect tetrahedral (~109.5°). A slight departure from this precise bond-angle, and the chemical

[78] This means that ice floats which is important for the development of life; if ice were to sink, it would causes bodies of waters to freeze solid and inhibit life. As such, ice floats and insulates the water beneath, keeping it in liquid state.

properties of water change considerably. Heavy water, where the hydrogen atoms are replaced with deuterium (with nuclei of one proton and one neutron) is chemically similar to water, having only a slightly smaller bond angle. This small difference though disrupts the biochemistry substantially. "D_2O in metazoans, both animals and plants, is completely inert and useless. In D_2O, seeds will not sprout and rats die of thirst given only D_2O to drink."[79]

Is the bond angle of water a direct and determined result of the time-independent Schrödinger equation? Molecules of this size might be the best place to look; beyond this, it becomes too complicated.

Appendix: DNA And Protein Structure

Protein structure is incredibly complex. Long polymers link up and fold into a shape that is representable by its 'solvent-accessible surface.' This is basically a constant-energy surface of the potential-energy distribution that results from all the charges within the molecule all 'added up.'[80] These shapes assume various roles: links for building larger structures, 'keys' for 'locks', platforms for other reactions, etc. The precision that these shapes are required to have in order to carry out their 'tasks' is remarkable.

Even for the polymers to fold into the required shape seems (metaphorically) paradoxical. The molecular biologist Cyrus Levinthal noted that if an average folding protein were to explore every possible configuration before 'coming to rest,' it would require timescales much greater than the age of the universe. Yet, proteins fold into their required shape in a few milliseconds typically. This 'paradox'[81] is resolved by the fact that the protein does not explore all possibilities, but follows a deterministic path down a funnel-like energy landscape. So not only does biochemistry have to have the right shapes, it has to get to those shapes *fast*.

This is the picture of how all bio-molecular processes are believed to occur - through deterministic paths where shapes and energy levels all conspire to keep organisms in constant flux. While it is possible[82] that this is all reducible to Schrödinger's equation, from the view point of ontologically rich scenarios such as theism and a Multiverse, the notion that there is 'emergent complexity' not discernible from the Schrödinger equation does not seem so implausible.

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[79] Barrow and Tipler, *The Anthropic Cosmological Principle*, 541.

[80] Adding them up means solving the Schrödinger equation. This is practically impossible *ab initio*.

[81] Whether there is a formal paradox here is questionable; the main point is that the problem of figuring out the folding structure of such proteins is short-handedly referred to by the phrase 'Levinthal's Paradox.'

[82] That is, epistemically possible in so far as nobody knows; the point though is that it might not *actually* be possible.