Inquiry, 43, 341–52

There Is No Adequate Definition of 'Fine-tuned for Life'

Neil A. Manson
University of Aberdeen

The discovery that the universe is fine-tuned for life – a discovery to which the phrase 'the anthropic principle' is often applied – has prompted much extra-cosmic speculation by philosophers, theologians, and theoretical physicists. Such speculation is referred to as extra-cosmic because an inference is made to the existence either of one unobservable entity that is distinct from the cosmos and any of its parts (God) or of many such entities (multiple universes). In this article a case is mounted for the sceptical position that cosmic fine-tuning does not support an inference to anything extra-cosmic. To that end three definitions of 'fine-tuned for life' are proposed: the 'slight difference' definition, the (unconditional) probability definition, and John Leslie's conditional probability definition. These three definitions are the only ones suggested by the relevant literature on fine-tuning and the anthropic principle. Since on none of them do claims of fine-tuning warrant an inference to something extra-cosmic, it is concluded that there is no definition of 'fine-tuned for life' serving this function.

Old-fashioned metaphysical speculation has received a boost in recent years from the burgeoning literature on the anthropic principle. That principle, first articulated by Brandon Carter (1998) in the early 1970s, surveyed exhaustively by Barrow and Tipler (1986), and introduced to philosophers by John Leslie (1989), has prompted both re-examination of the traditional Teleological argument for God's existence and consideration of the possibility of universes distinct from ours. The term 'anthropic principle' is unfortunately often applied to the data for which that principle is supposed to account rather than the principle itself; this article concerns the data and not the principle. Since the data in question are simply all the instances wherein a given cosmic parameter is 'fine-tuned for life', let me say a bit about what fine-tuning for life is supposed to be.

The picture of the universe painted by modern particle physics and Big Bang cosmology is very detailed. We can imagine this picture presented in the form of a list of equations consisting of the fundamental physical parameters that a universe might have on the left-hand side and the numerical values those parameters actually have in our universe on the right-hand side. The list would include lines such as this (for the mass of the proton):

* I thank Robin Collins, Gordon Graham, Brent Mundy, Graham Oppy, Tomasz Placek, and Peter van Inwagen for their help in developing the ideas presented in this paper.

'$M_p = 938.28$ MeV'. Describing the universe this way naturally suggests asking why the parameters have the values they actually have as opposed to some other values. In the course of addressing this question, physicists and cosmologists have discovered that many of the parameters on this list possess the following property: if its actual value is sufficiently altered while the values of all the other parameters are held constant, the resulting list ceases to describe a life-permitting universe. Parameters possessing this property are said to be 'fine-tuned for life'.

That so many cosmic parameters are fine-tuned for life has been thought by many physicists and cosmologists (and, later, philosophers and theologians) to pose a problem. The anthropic principle is thought to be one solution. It tells us this: given that we are around to observe the universe, the universe necessarily meets whatever conditions our existence imposes. This has given rise to the suggestion that our universe is but one of a vast multitude of universes, thus making it no surprise that one universe in the vast multitude happens to permit life. A wholly different explanation for fine-tuning is that the universe is the product of a designer of great power and intelligence who exists outside of the physical universe.

Those who argue either to multiple universes or to a designer think there is something about cosmic fine-tuning for life which demands an explanation and which warrants an inference to some thing (or things) outside the universe. Whether they are right in so thinking depends on how they define 'fine-tuned for life'. Based on the literature there appear to be several possible definitions.

I. The 'Slight Difference' Definition

The most common way of stating claims of fine-tuning for life is in terms of counterfactual conditionals, wherein expressions such as 'slight difference', 'small change', 'delicate balance', 'precise', 'different by n%', 'different by one part in 10^n', and 'tuned to the nth decimal place' appear in the antecedent. Consider the following quotations from Stephen Hawking and Lee Smolin.

> The remarkable fact is that the values of these [fundamental] numbers seem to have been very finely adjusted to make possible the development of life. For example if the electric charge of the electron had been only slightly different, stars either would have been unable to burn hydrogen and helium, or else they would not have exploded. (Hawking [1988], p. 125)

> . . . the existence of stars rests on several delicate balances between the different forces in nature. These require that the parameters that govern how strongly these forces act be tuned just so. In many cases, a small turn of the dial in one direction or another results in a world not only without stars, but with much less structure than our universe. (Smolin [1997], p. 37)

Such statements suggest the following definition:

Def. 1: A cosmic parameter *P* is fine-tuned for life if and only if life could not have arisen had the numerical value of *P* been slightly different.

I will dub parameters that are fine-tuned in this sense 'fine-tuned$_1$'.

The problem with this definition is that to say a parameter is fine-tuned$_1$ is to say nothing about probability. Consequently, fine-tuning$_1$ statements can play no role in Bayesian-style arguments, because Bayesian arguments require probability statements as inputs. Yet those who argue from fine-tuning to something extra-cosmic most often present themselves as applying a Bayesian model of inference (rather than making an argument from analogy of the sort Paley mounted). Whether they be arguing for God (e.g. Swinburne [1989]), multiple universes (e.g. Carter [1993] and Smolin [1997]), or both (e.g. Leslie [1989]), they all claim that the probability of getting a universe with life is far greater conditional on the existence of the sort of extra-cosmic entity they favor than it is conditional on there being just one universe the features of which are determined by chance. Though superficially similar, claims about what things would have been like if conditions had been slightly different are not at all equivalent to probabilities. Consider that a certain nut would not fit onto a certain one-centimetre-wide bolt if that bolt were a millimetre wider or narrower. It does not follow that the probability of the nut's fitting the bolt is one in ten. Indeed, nothing about probability follows at all.

This point alone is sufficient to rule fine-tuning$_1$ inadequate for the purposes of Bayesian extra-cosmic arguments. Even supposing there are non-Bayesian extra-cosmic arguments, however, a further problem remains: statements of fine-tuning$_1$ are useless in the absence of a metric for differences. Such a metric is needed in order to answer the question aptly asked by Robert K. Clifton ([1991], p. 30): 'how is one to distinguish an instance of fine-tuning from mere "coarse"-tuning?' Consider this selection from the data set Leslie ([1989], pp. 3–5) presents as evidence that the universe is fine-tuned.

- [the universe's] rate of expansion at early instants needed to be fine tuned to perhaps one part in 10^{55} (which is 10 followed by 54 zeros) . . .
- For carbon to be created in quantity inside stars *the nuclear strong force* must be to within perhaps as little as 1 percent neither stronger nor weaker than it is . . .
- Gravity also needs fine-tuning for stars and planets to form, and for stars to burn stably over billions of years. It is roughly 10^{39} times weaker than electromagnetism. Had it been only 10^{33} times weaker, stars would be a billion times less massive and would burn a million times faster.

Putting these as percentages, in the first case Leslie is saying of a certain parameter that if it had differed by one-hundred thousand trillion trillion

trillion trillionth *of* a percent, life would not be possible; in the second, one or two percent; and in the third, one-hundred million percent. In virtue of what do all of these count as cases of *fine*-tuning? Without a metric to supplement definition 1, we have no answer.

Perhaps it is the lack of probabilities and the lack of a metric which explains why there are so many mischievous presentations of fine-tuning$_1$. Consider some facts John Jefferson Davis ([1987], pp. 140–1) calls to our attention: 'If the mass of neutrinos were 5×10^{-34} instead of 5×10^{-35} kg, because of their great abundance in the universe, the additional gravitational mass would result in a *contracting* rather than *expanding* universe.' Given that particle masses are being measured in kilograms, is this any surprise? No astonishment is warranted by the fact (henceforth 'the Jordan fact') that, if he had been one part in 10^{16} of a light-year shorter (that is, one metre shorter), Michael Jordan would not have been the world's greatest basketball player. Again, Davis says: 'If gravity were stronger by one part in 10^{40}, there would long ago have been a catastrophic *collapse* of the universe (the "Big Crunch") instead of its present expansion.' Yet the one part in 10^{40} to which Davis refers is a part of the unit of measure for the gravitational constant, not a part of the gravitational constant itself. Compare this again to the Jordan fact. It is true only if we are talking about parts of a light-year rather than parts of Jordan's height; being one ten-trillionth of a millimetre shorter would not affect Jordan's basketball abilities a bit. As crude as these confusions sound, they are oft-committed in discussions of fine-tuning and the anthropic principle.

Such complaints are not unprecedented. More than sixty years ago, Herbert Dingle criticized on similar grounds the hubbub over the 'large-number coincidences' which exercised many of his contemporaries (see Barrow and Tipler [1986], ch. 4).

In essence, P. A. M. Dirac's argument is this. Large numbers need an entirely different type of explanation from small ones (since the number of pure numbers is infinite the distinction is meaningless, but meaning seems to be irrelevant to these considerations). If, from an indefinitely wide choice, we select a certain unit of time ('say the unit e^2/mc^3), the age of the universe according to one cosmological speculation is 'about' equal to the square root of the number of protons in the universe according to another, and to the ratio of certain electronic forces (Dingle [1937], p. 786).

The age to which Dingle refers is 10^{39}, and the number of protons was estimated to be 10^{78}. Dingle complained that this coincidence is only the result of the unit of time selected – a selection, he said, that was made from 'an indefinitely wide choice'. My complaint about Davis's use of kilograms to measure the mass of the neutrino echoes Dingle's. As for Dingle's charge that there being an infinite number of pure numbers renders meaningless the large number/small number distinction, it will be taken up in the next section.

II. The (Unconditional) Probability Definition

Supposing they acknowledge the deficiencies of definition 1 and the shortcomings of presenting the facts of fine-tuning in terms of counterfactual conditionals, those advancing extra-cosmic arguments might plead guilty only to brevity. Implicit in their arguments, they will say, is the supposition that the conditions are met which warrant treating statements of fine-tuning$_1$ as indicating the extreme improbability of getting life-permitting parameter values. Thus when they talk about fine-tuning, they have the following definition in mind.

Def. 2: A cosmic parameter *P* is fine-tuned for life if and only if the probability that *P* takes a life-permitting value is extremely low.

I will describe parameters that are fine-tuned in this sense as 'fine-tuned$_2$'. It is clear that if a cosmic parameter is fine-tuned$_2$, then that fact can be used in Bayesian arguments for something extra-cosmic (though those arguments may fail for other reasons).

For definition 2 to be useful, however, some specification will have to be given of (a) the range of values *P* could have taken (henceforth 'range') and (b) the probability distribution for the values in that range (henceforth 'probability distribution'). The theories of range and probability distribution may vary in their specifics, e.g. that the range is the set of real numbers and that the probability measure on that range consists of Borel subsets of the real numbers. The important point, however, is that the theories of range and probability distribution will have to combine in such a way that they justify treating the probability of *P*'s taking a life-permitting value as extremely small. They could do so in several ways. The theories could be that (a_1) the range of possible values for *P* is vast relative to the life-permitting range of values for *P*, and (b_1) the probability distribution for that range is not significantly biased towards the life-permitting range. They could be that (a_2) the range of possible values for *P* is not vast relative to the life-permitting range of values for *P*, but (b_2) the probability distribution for that range is significantly biased against the life-permitting range. (Note that even if the probability distribution for a variable is biased towards a particular value, this does not mean we should not be surprised if the variable takes precisely that value; if we flip a coin 2×10^{100} times, getting exactly 10^{100} heads would be startling.) They could be that (a_1) and (b_2). The important point is that getting from fine-tuning$_1$ to fine-tuning$_2$ requires theories about both range and probability distribution.

To see this, consider, again, the Jordan fact. While his height in light-years is fine-tuned (in a sense analogous to that provided in definition 1), this is not impressive because (a_h) the range of greatness-permitting biologically possible values for Jordan's height, while minuscule compared to a light-year, is not too small relative to the range of biologically possible values for

Jordan's height, and because (b_h) Jordan's height, we presume, had a fairly good chance of ending up in the greatness-permitting biologically possible range. Compare this to the case of his making five shots in succession. On any given shot, he could have missed the basket wildly. Even so, his making five consecutive shots is not too surprising because although (a_s) the range of possible trajectories for one of his shots *is* vast relative to the range of possible basket-making trajectories for that shot, Jordan's great skill means that (b_s) the probability distribution for the range of possible trajectories is heavily skewed towards the range of basket-making trajectories. While each of his shots is, in a way, fine-tuned$_1$ is making five in a row is not very surprising, even if we grant (a_s).

Given that arguments from fine-tuning$_2$ to things extra-cosmic implicitly rely on theories of range and probability distribution, it might surprise the reader to know there is only a handful of instances wherein such theories are discussed explicitly. Ernan McMullin ([1993], p. 361) writes about 'the cosmogonic principle of indifference, or just the indifference principle, for short'. He identifies this as the principle that the universe is the way it is as the result of chance, and takes it to imply that the range of possible values for the mass density of the universe is unrestricted.

The mass density of the universe today is relatively close to the density corresponding to the borderline between an open and a closed universe. The ratio of these densities (Ω) is believed to lie somewhere between the values of 2 and 1. So the universe, in geometrical terms, is relatively 'flat'. The problem is that to reach this condition today the value of Ω shortly after the Big Bang would have had to be almost exactly 1; to achieve this, the initial expansion rate would have to be 'tuned' to an accuracy (so one estimate went) of one part in 10^{55}. According to the indifference principle, *any* initial value of Ω should have been possible. So this extraordinarily tight restriction on the initial cosmic conditions poses a problem (McMullin [1993], p. 378).

McMullin does not say whether this implication of the indifference principle – that *any* initial value of Ω should have been possible – is coherent or acceptable. Incidentally, McMullin ([1993], pp. 378–9) later asks 'why is the only one among 10^{55} possible initial states . . . the one that is actually realized?' To say Ω requires tuning to one part in 10^{55} is, he seems to think, just to say that there are 10^{55} possible initial states of which only one permits life. This is just another instance of the sort of confusion indicated in the first section of this paper.

The problem with a position such as McMullin's is astutely noted by Paul Davies ([1992], pp. 204–5): 'If the range is infinite, then any finite range of values might be considered to have zero probability of being selected. But then we should be equally surprised however weakly the requirements for life constrain those values. This is surely a *reductio ad absurdum* of the whole argument.' Another way of making essentially the same objection is to say that McMullin's indifference principle guarantees fine-tuning$_2$ on the cheap. To prove that the universe is fine-tuned$_2$ for life, all one would need do is show that there is at least one cosmic parameter for which life constrains the possible values to a finite interval. Then one would have shown that the probability of a life-permitting universe is zero no matter how large that interval. Furthermore, there would be no need to find any further cases of fine-tuning$_2$, for no additional evidence could make it any less likely on the chance hypothesis that the universe is such as to permit life.

These consequences of endorsing McMullin's indifference principle may not be devastating *per se*. Indeed, those inferring extra-cosmic entities from fine-tuning$_2$ might say their arguments are even stronger than they initially supposed. Setting this response aside, there would still be the problem that it appears all of the work is being done by *a priori* assumptions. Arguments from fine-tuning$_2$ begin to look less like the traditional Teleological argument and more like the Cosmological argument. As William Rowe ([1998], p. 4) notes, both arguments, while technically a posteriori, differ substantially. The former requires its proponents to identify facts about the world far richer, more complicated, and more difficult to establish than the simple fact that it exists. Furthermore, the Teleological argument is supposed to be inductive, so that the truth of its premisses does not guarantee the truth of its conclusion. Given McMullin's indifference principle, however, it seems very easy to establish the fact that warrants a Bayesian argument to something extra-cosmic. All one would need establish would be some fact such as that there would be no life if protons were more massive than Mount Everest. Furthermore, that there would be zero probability of getting life (conditional on the chance hypothesis) comes uncomfortably close to guaranteeing the falsity of the chance hypothesis.

The alternative to a McMullin-style indifference principle would be some restricting theory about the range of values the cosmic parameters could have had. Suppose, for example, there were a theory according to which Ω could only have been some number in the interval $\{10^{-10}, 10^{10}\}$. Also suppose it were shown that life could evolve only if Ω were exceptionally close to 1. In this case we *can* imagine having discovered that life constrained Ω to an interval sufficiently large to make Ω's actually falling in that interval unsurprising. This would enable advocates of the extra-cosmic to avoid Davies's objection. The price of such a theory, however, is the appearance of arbitrariness. Proponents of such a theory would have to explain what prevents the parameter values from being just a little bit bigger than their theoretical maxima.

There may be intuitions at work suggesting an implicit range for any given cosmic parameter *P*. Let *N* stand for the numerical value of *P*. Now suppose one thought there might have been no universe at all, and that one represented this possibility to oneself as a situation wherein every cosmic parameter takes a value of zero. If one believed that the value of P is N but could have been zero, then one might reasonably suppose P could have taken any value in the interval $\{0, N\}$. The upshot of this is that as N gets larger, so does the perceived range of possible values for P. We can see Leslie working with this intuition as he tries to put his disparate cases of fine-tuning on the same footing.

> . . . force strengths and particle masses are distributed across enormous ranges. The nuclear strong force is (roughly) a hundred times stronger than electromagnetism, which is in turn ten thousand times stronger than the nuclear weak force, which is itself some ten thousand billion billion billion times stronger than gravity. So we can well be impressed by any apparent need for a force to be 'just right' even to within a factor of ten, let alone to within one part in a hundred or in 10^{100} – especially when nobody is sure why the strongest force tugs any more powerfully than the weakest. (Leslie [1989], p. 6)

Leslie says, in effect, that for all we know the strongest force could have had the strength of the weakest force; that is, the strongest force could have had a value very close to zero. And since the strongest force could have been as weak as the weakest force, implicitly the strongest force could have been any strength *between* the strength of the weakest force and its actual strength. Thus Leslie imagines a wide range of possible values for the cosmic parameters, including those cosmic parameters which take large values.

Such intuitions, however, are no substitute for a well-grounded theory of range and probability distribution. Few such theories are on offer, perhaps for the reasons already indicated. John Earman and Jesus Mosterin ([1999], pp. 31–34) note that attempts have been made to provide a measure for the range of Friedmann–Robertson–Walker models of the universe. As they note, however, these theories do not work in the absence of a specification of the probability distribution over these measures. The Hawking group provides no such specification with respect to Friedmann–Robertson–Walker models. The Belinskii–Khalatnikov group does, but only by making the (suspect) assumption that ranges of equal area have equal probabilities of housing a universe. Given that there are no well-grounded theories of range and probability distribution for the cosmic parameters, and given the drawbacks of endorsing McMullin's indifference principle, it seems that those who argue to something extra-cosmic cannot base their arguments on the universe's being fine-tuned$_2$.

III. Leslie's Conditional Probability Account

The preceding objections to fine-tuning$_2$ presuppose that the life-permitting parameter values must be set against a background consisting of all possible parameter values. Leslie, however, contends that we need not concern ourselves with all possible values. If life-permitting universes were rare within the set of possible universes that are very much like this one, he says, that itself would be surprising. He makes this point by telling the story of the fly on the wall.

A wall bears a fly (or a tiny group of flies) surrounded by a largish empty area. The fly (or one of the group) is hit by a bullet. With appropriate background assumptions . . . we might fairly confidently say, 'Many bullets are hitting the wall and/or a marksman fired this particular bullet', without bothering whether distant areas of the wall are thick with flies. All that is relevant is that there are no further flies locally (Leslie [1989], pp. 17–18).

Leslie thus thinks he need not establish that only an extremely tiny area of the possibility space for universes is life-permitting; he only need consider the 'local area' of universes. This is important, he thinks, because we are ignorant of the features of possible universes that are radically different from ours. For all we know we might find that life-permitting universes are abundant once we start considering radically different universes. That would not matter, just as the fact that hydrogen is the most common element in the universe would make it no less suspicious that a dead man's lungs are full of hydrogen gas.

Thus we have a third proposed definition of fine-tuning, and we can dub parameters meeting this description 'fine-tuned$_3$'.

Def. 3: A cosmic parameter *P* is fine-tuned for life if and only if the probability that *P* takes a life-permitting value (conditional on selecting a value from *P*'s local area) is extremely low.

Let me flesh this out a bit. We are to imagine that there is a space mapping possible universes. Within this space there will be contiguous portions such that our universe is represented somewhere within their boundaries. Some of these portions will be gerrymandered, while others (the sort Leslie has in mind, presumably) won't. Let us call the latter kind of portions 'areas'. Thus if the space of possible universes is unbounded (as McMullin suggests), then the point representing our universe will have an infinite number of areas encompassing it.

Given this picture, what is it for an area to be local? I see no natural answer to this question. Surely it is unacceptable to identify as 'local' to our universe any area such that that area is just large enough to make life-permitting universes rare within its bounds. Supposing, contrary to fact, that the theoretical investigations of physical cosmologists revealed that life could have evolved had Ω been any number in the interval $\{10^{-10}, 10^{10}\}$, but that life could not have evolved had Ω been any number in the interval $\{10^{10}, 10^{100}\}$. It would not be fair play to argue to something extra-cosmic on the grounds that life-permitting values for Ω are extremely rare in the interval $\{10^{-10}, 10^{100}\}$. If such a manoeuvre were permissible, then (as with fine-tuning$_2$ given McMullin's indifference principle) the rules of the game are such as to make it far too easy for a parameter to count as fine-tuned$_3$. All advocates of the extra-cosmic would need do is expand the 'local' area until it is big enough to make the life-permitting portion of it relatively minuscule. Then again, if this were permissible, those sceptical of arguments to extra-cosmic entities could retort that Ω doesn't need fine-tuning, because life-permitting universes are exceedingly common in the interval $\{\Omega + (\Omega/10^{55}), \Omega - (\Omega/10^{55})\}$.

This is a fool's game. We are drawn into it only if we are persuaded by Leslie's story of the fly on the wall. That story works, however, only because Leslie illicitly imports a perspective. We know how big we are, we know how big flies are relative to us, and we know what it is for an empty area surrounding a fly to be 'largish' relative to a fly. There is no correspondingly natural perspective when it comes to surveying the space of sets of possible parameter values. Given that there is no such perspective, I have to conclude that fine-tuning$_3$, like fine-tuning$_1$ and fine-tuning$_2$ is an inadequate basis on which to argue to something extra-cosmic. If there is some definition of 'fine-tuned for life' that can function to generate arguments to things extra-cosmic, I have yet to encounter it.

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Received 7 March 2000

Neil A. Manson, Department of Philosophy, University of Aberdeen, Aberdeen AB24 3UB, Scotland, UK. E-mail: n.manson@abdn.ac.uk