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The Teleological Argument: An Exploration of the Fine-Tuning of the Universe

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1. Introduction: Setting Up the Argument

1.1. Nature of project and summary of sections

Historically, the argument from design probably has been the most widely cited argument for the existence of God, both in the West and the East (such as in theistic schools of Hinduism). Modern scientific discoveries, particularly the discovery beginning around the 1950s that the fundamental structure of the universe is "balanced on a razor's edge" for the existence of life, have given this argument significant new force in the last 30 years, with several books and many essays written on it.[1] This precise setting of the structure of the universe for life is called the "fine-tuning of the cosmos." This fine-tuning falls into three major categories: that of the laws of nature, that of the constants of physics, and that of the initial conditions of the universe, each of which we shall explore in Section 2. As will become clear in Section 5.2, the sort of life that is most significant for the argument is that of embodied moral agents, of which humans are one example.

This chapter is a highly abridged version of an in-process book-length project in which I argue for the existence of God based on this fine-tuning of the cosmos for life along with the beauty and intelligibility of the laws of nature. The main purpose of the book is to put this argument on as rigorous as possible scientific and philosophical foundation. Although this chapter has the same purpose, it will focus solely on the argument based on the fine-tuning for life, although in my judgment the argument based on beauty and intelligibility is as strong.

The sections of this chapter are arranged as follows. In Section 1.2, I present some key terms and definitions for easy reference. In Section 1.3, I present the basic form of what I call the *core* fine-tuning argument for the existence of God. This argument is explicated in terms of what I call the *restricted version of the Likelihood Principle*. In Section 1.4, I present an alternative way of formulating the argument using what I call the *method of probabilistic*

1. For shorter versions of the fine-tuning argument appropriate for undergraduates, see Collins (2002, 2007, 2008), Leslie (1988, 1998), and Collins (www.fine-tuning.org). For other book-length treatments of the fine-tuning argument, see Leslie (1989) and Holder (2004).

tension. In Sections 2.1–2.6, I present the evidence for fine-tuning and consider some of the main criticisms of this evidence.

Since I shall formulate the argument in Sections 1.3 and 1.4 in terms of certain *conditional epistemic probabilities*, I need to develop an account of conditional epistemic probability and a general method for determining the degree of conditional epistemic probability that one proposition has on another. I do this in Sections 3.1–3.3. In Sections 4.1–4.5, I address some further critical issues for my formulation of the fine-tuning argument, namely, the appropriate background information to use in the argument and the appropriate comparison range of values for the constants of physics. In Sections 5.1 and 5.2, I complete the core fine-tuning argument by using the results of the previous sections to derive the premises of the main argument presented in Sections 1.3 and 1.4.

In Sections 6.1–6.3, I address the so-called multiverse hypothesis as an alternative explanation of the fine-tuning, or at least as a way of undermining the fine-tuning argument for theism. The multiverse hypothesis is widely considered the leading alternative to a theistic explanation. In Sections 7.1–7.5, I reply to various miscellaneous objections to the fine-tuning argument, such as the so-called "who designed God?" objection. Finally, in Section 8, I conclude the entire argument.

My overall approach will be to present a version of the fine-tuning argument that is more rigorous than its predecessors by presenting the argument in a step-by-step fashion and then justifying each step using widely used principles of reasoning. This way of developing the argument will not only show that the argument can be developed in a philosophically principled way, but it automatically will answer many of the criticisms that have been raised against it; it also will help us go beyond a mere "battle of intuitions" between advocates and critics of the argument. Further, as much as possible, I shall avoid using theories of confirmation that attempt to account for everyday and scientific forms of reasoning but whose claims go significantly beyond what these forms of reasoning demand. Thus, for instance, I will avoid appealing to *prior* probabilities and to notions of purely logical probability that claim that relations of probability exist completely independently of human cognizers (see e.g. Sections 1.3 and 3.2).

1.2. Some key definitions, terminologies, and abbreviations

In this section, I shall define some key terminologies and abbreviations that are used in more than one section. This will help the reader keep track of my terms and symbolisms.

1 **Embodied moral agents.** An "embodied moral agent" will be defined as an embodied conscious being that can make morally significant choices, without prejudging the status of moral truths. Our main concern, however, will be with embodied beings that are relevantly similar to humans – that is, who exist in a world with fixed laws and who can significantly affect each other for good or ill. Thus, whenever I talk about embodied moral agents, this is the type of agent I shall have in mind.

2 **The existence of a life-permitting universe (LPU).** This will always mean the existence of a material spatiotemporal reality that can support embodied moral agents, not merely life of some sort. Indeed, in every case where I use the word "life," I shall have in mind embodied moral agents as the relevant kind of life. The reason that embodied moral agents are the relevant kind of life will become clear in Section 5.2, where I argue that LPU is not improbable under theism. Throughout, it will be

assumed that the existence of such beings requires a high degree of organized material complexity, such as we find in the brains of higher-order animals.

3 **Fine-tuning of the universe; existence of a fine-tuned universe; fine-tuning evidence; fine-tuning data.** To stay in conformity with the literature, I shall mean by the "fine-tuning of the universe" or the "existence of a fine-tuned universe" the conjunction of the following two claims: (i) the claim that the laws and values of the constants of physics, and the initial conditions of any universe with the same laws as our universe, must be set in a seemingly very precise way for the universe to support life; and (ii) the claim that such a universe exists, or when the background information includes the information that there is only one universe, the claim that *this* universe is life-permitting, where *this* is an indexical that picks out the one universe that actually exists. *When I speak of the "fine-tuning evidence (data)," or "the evidence (data) of fine-tuning," or variations of these, I shall be referring only to claim (i).* The reason for this is that "evidence" and "data" implicitly refer to what physicists have discovered. Clearly, physicists have not discovered that the laws, constants, and initial conditions are life-permitting since we always knew that based on our existence. Rather, they have discovered claim (i). When I attempt rigorously to formulate the argument, the distinction between claim (i) and claim (ii), and the distinction between the "fine-tuning of the universe" and the "fine-tuning evidence (or data)" should be kept in mind.

4 **Fine-tuning of a constant C of physics.** When discussing a constant C of physics (see Sections 2.3 and 4.2), I shall use the term "fine-tuning" specifically to refer to the claim that the life-permitting range of C – that is, the range of values that allows for life – is very small compared with the some properly chosen "comparison range" for that constant. (For how to choose this comparison range, see Sections 4.3 and 4.4.) In connection with a constant C, the term "fine-tuning" will never be used to include the claim that it has a life-permitting value.

5 **Constant C has a life-permitting value (Lpc).** This denotes the claim that the value of a constant C is such that, given the laws of nature, the initial conditions of the universe, and the values of the other constants, the universe would allow for the existence of the relevant type of life – namely, embodied moral agents.

6 **The Theistic hypothesis (T).** According to this hypothesis, there exists an omnipotent, omniscient, everlasting or eternal, perfectly free creator of the universe whose existence does not depend on anything outside itself.

7 **The naturalistic single-universe hypothesis (NSU).** This is the hypothesis that there is only one universe, the existence of which is an unexplained, brute given, and that within that universe the laws and constants of physics do not significantly vary from one space-time region to another. NSU does not build in any hypothesis about the structure of the universe that does exist, other than that it is some sort of material, spatiotemporal reality that obeys physical laws; it also excludes any transcendent explanation of the universe, be that explanation theistic or nontheistic.

8 **Multiverse hypothesis.** This is the hypothesis that there are many universes or regions of space-time in which the constants and initial conditions of the universe, and in some versions the laws themselves, vary from universe to universe. The *naturalistic multiverse hypothesis* is the hypothesis that there is no transcendent explanation for such a multiverse.

9 **P(A|B) and conditional epistemic probability.** P(A|B) represents the *conditional epistemic probability* of a Proposition A on another Proposition B. See Sections 3.1 and 3.2 for details.

10 **Background information k and k′.** k refers to our total background information, whereas k′ refers to some appropriately chosen background information – for example, for the case of the fine-tuning of the constants, k′ is the total background information minus the fact that a particular constant C has a life-permitting value. (See Sections 4.1–4.4 for how to determine k′ for the fine-tuning argument.)

11 **Other symbols.** $\ll$ will always mean "much, much less than" – for example, $P(A|B) \ll 1$ will mean that $P(A|B)$ is very close to zero since $P(A|B)$ cannot have a negative value. $\sim P(A|B) \ll 1$ will mean that it is not the case that $P(A|B) \ll 1$. W_r will usually refer to the width of the life-permitting range of a particular constant C of physics, and W_R will usually refer to the width of the "comparison range" for that constant, which we argue is typically the EI region (see Section 4.4). The EI region for a constant will refer to the "epistemically illuminated" region – that is, the region of values for C for which we can determine whether they are life-permitting. A constant is fine-tuned if $W_r/W_R \ll 1$; "BB" stands for "Boltzmann brain" (see Sections 6.3.3 and 6.3.4).

1.3. The basic argument presented: likelihood approach

My basic argument first claims that, given the fine-tuning evidence, LPU strongly supports T over the NSU. I call this the *core* fine-tuning argument. After developing this argument in Sections 2 through 5, I then present arguments for preferring T over the multiverse hypothesis (Section 6). Finally, in Section 8, I shall briefly consider other possible alternative explanations of the fine-tuning.

The core fine-tuning argument relies on a standard Principle of Confirmation theory, the so-called *Likelihood Principle.* This principle can be stated as follows. Let h_1 and h_2 be two competing hypotheses. According to the Likelihood Principle, an observation e counts as evidence in favor of hypothesis h_1 over h_2 if the observation is more probable under h_1 than h_2. Put symbolically, e counts in favor of h_1 over h_2 if $P(e|h_1) > P(e|h_2)$, where $P(e|h_1)$ and $P(e|h_2)$ represent the *conditional probability* of e on h_1 and h_2, respectively. Moreover, the degree to which the evidence counts in favor of one hypothesis over another is proportional to the degree to which e is more probable under h_1 than h_2: specifically, it is proportional to $P(e|h_1)/P(e|h_2)$.[2]

The Likelihood Principle appears to be sound under all interpretations of probability. The type of probability that we shall be concerned with is what is called conditional *epistemic* probability. The conditional epistemic probability of a Proposition A on a Proposition B can be defined roughly as the degree to which Proposition B, in and of itself,

2. There are many reasons why the Likelihood Principle should be accepted (e.g. see Edwards 1972; Royall 1997; Forster & Sober 2001; Sober 2002); for the purposes of this chapter, I take what I call the *restricted version of the Likelihood Principle* (see further discussion) as providing a sufficient condition for when evidence e supports a hypothesis, h_1, over another, h_2. For a counterexample to the Likelihood Principle's being a necessary condition, see Forster (2006). For an application of the Likelihood Principle to arguments for design, see Sober (2005). (I address Sober's main criticism of the fine-tuning argument in Sections 3.2, 5.2, and 7.5.)

The Likelihood Principle can be derived from the so-called odds form of Bayes's Theorem, which also allows one to give a precise statement of the degree to which evidence counts in favor of one hypothesis over another. The odds form of Bayes's Theorem is $P(h_1|e)/P(h_2|e) = [P(h_1)/P(h_2)] \times [P(e|h_1)/P(e|h_2)]$. The Likelihood Principle, however, does not require the applicability or truth of Bayes's Theorem and can be given independent justification by appealing to our normal epistemic practices.

supports or leads us to expect A to be true. In Section 3.2, I shall explicate this notion of probability in much more detail. Put in terms of epistemic probability, the Likelihood Principle can be reworded in terms of degrees of expectation instead of probability, in which case it becomes what I call the *Expectation Principle*. According to the Expectation Principle, if an event or state of affairs e is more to be expected under one hypothesis, h_1, than another, h_2, it counts as evidence in favor of h_1 over h_2 – that is, in favor of the hypothesis under which it has the highest expectation. The strength of the evidence is proportional to the relative degree to which it is more to be expected under h_1 than h_2. Rewording the Likelihood Principle in terms of expectation is particularly helpful for those trained in the sciences, who are not familiar with epistemic probability and therefore tend to confuse it with other kinds of probability even when they are aware of the distinction.

Because of certain potential counterexamples, I shall use what I call the *restricted version* of the Likelihood Principle, although I shall often refer to it simply as the Likelihood Principle. The restricted version limits the applicability of the Likelihood Principle to cases in which the hypothesis being confirmed is non-*ad hoc*. A sufficient condition for a hypothesis being non-*ad hoc* (in the sense used here) is that there are independent motivations for believing the hypothesis apart from the confirming data e, or for the hypothesis to have been widely advocated prior to the confirming evidence. To illustrate the need for the restricted version, suppose that I roll a die 20 times and it comes up some apparently random sequence of numbers – say 2, 6, 4, 3, 1, 5, 6, 4, 3, 2, 1, 6, 2, 4, 4, 1, 3, 6, 6, 1. The probability of its coming up in this sequence is one in 3.6×10^{15}, or about one in a million billion. To explain this occurrence, suppose I invented the hypothesis that there is a demon whose favorite number is just the aforementioned sequence of numbers (i.e. 26431564321624413661), and that this demon had a strong desire for that sequence to turn up when I rolled the die. Now, if this demon hypothesis were true, then the fact that the die came up in this sequence would be expected – that is, the sequence would not be epistemically improbable. Consequently, by the standard Likelihood Principle, the occurrence of this sequence would strongly confirm the demon hypothesis over the chance hypothesis. But this seems counterintuitive: given a sort of commonsense notion of confirmation, it does not seem that the demon hypothesis is confirmed.

Now consider a modification of the demon case in which, prior to my rolling the die, a group of occultists claimed to have a religious experience of a demon they called "Groodal," who they claimed revealed that her favorite number was 2643156432162441366, and that she strongly desired that number be realized in some continuous sequence of die rolls in the near future. Suppose they wrote this all down in front of many reliable witnesses days before I rolled the die. Certainly, it seems that the sequence of die rolls would count as evidence in favor of the Groodal hypothesis over the chance hypothesis. The relevant difference between this and the previous case is that in this case the Groodal hypothesis was already advocated prior to the rolling of the die, and thus the restricted Likelihood Principle implies that the sequence of die rolls confirms the Groodal hypothesis.[3]

3. The restricted version of the Likelihood Principle is not the only way of dealing with the sort of counterexample raised by the first demon case. Another way is to claim that, contrary to our intuitions, in the appropriate technical sense given by Bayes's Theorem, the sequence really does confirm the demon hypothesis, but never enough to make it probable since its prior probability is so low. For the purposes of this chapter, however, I am trying to stay as close to our intuitions about evidence as possible and hence prefer restricting the Likelihood Principle to deal with these purported counterexamples.

Using the restricted version of the Likelihood Principle, the core fine-tuning argument can be stated as follows:

(1) Given the fine-tuning evidence, LPU is very, very epistemically unlikely under NSU: that is, $P(LPU|NSU \& k') \ll 1$, where k′ represents some appropriately chosen background information, and $\ll$ represents much, much less than (thus making $P(LPU|NSU \& k')$ close to zero).
(2) Given the fine-tuning evidence, LPU is not unlikely under T: that is, $\sim P(LPU|T \& k') \ll 1$.
(3) T was advocated prior to the fine-tuning evidence (and has independent motivation).
(4) Therefore, by the restricted version of the Likelihood Principle, LPU strongly supports T over NSU.

This argument is a valid argument since the conclusion (4) follows from the premises. Accordingly, the key issues for the argument will be justifying the premises and assessing the significance of the conclusion. Premise (3) seems obviously true since T was advocated long before the fine-tuning evidence came to light.[4] Supporting Premises (1) and (2) in as rigorous a way as possible will require delving into and resolving several further issues. First, we shall need to be more precise on what we mean by "epistemic" probability (Section 3.2) and to develop a preliminary theory of what it is that will be usable for our main argument. Second, we shall need to consider how epistemic probability is justified (Section 3.3). In particular, in Section 3.3.2, I argue for what I call the *restricted Principle of Indifference*. Third, we shall need to carefully determine what the appropriate background information k′ is (Sections 4.1–4.6). If, for example, we were to include in k′ everything we know about the world, including our existence, then both probabilities in Premises (1) and (2) will turn out to be 1.0 since our existence entails LPU. Determining k′ will also provide a comparison region of law structures (or values for the constants) to which we are comparing the life-permitting region (Section 4.4). Having done this, we shall be ready to complete the argument for Premises (1) and (2) in Sections 5.1 and 5.2 – for example, we shall justify Premise (1) for the case of the fine-tuning of the constants by appealing to the restricted version of the Principle of Indifference defended in Sections 3.3.1 and 3.3.2.

Finally, given that we can establish the conclusion, what is its significance? Even if LPU counts as strong evidence in favor of T over NSU, that does not itself establish that T is likely to be true, or even more likely to be true than NSU. In this way, LPU is much like fingerprints found on a murder weapon. Via the Likelihood Principle, a defendant's fingerprints' matching those on the weapon typically provide strong evidence for guilt because the jury correctly judges that it is very unlikely for this matching to occur if the defendant is not guilty (and claims to have never seen the murder weapon), whereas it is not unexpected if the defendant actually used the murder weapon. Although such a

4. There is one worry about Premise (3) though: T was not advocated prior to the evidence of LPU since the life-permitting character of our universe follows from our existence and all the motivations for T are intertwined with the fact that we exist. If this is a real difficulty, one might need to use my alternative version of the fine-tuning argument, the method of *probabilistic tension* (Section 1.4), for which this problem clearly does not arise.

match can provide strong evidence that the defendant is guilty, one could not conclude merely from this alone that the defendant is guilty; one would also have to look at all the other evidence offered. Perhaps, for instance, ten reliable witnesses claimed to see the defendant at a party at the time of the shooting. In that case, by the restricted version of the Likelihood Principle, the matching would still count as significant evidence of guilt, but this evidence would be counterbalanced by the testimony of the witnesses. Similarly, we shall claim that the evidence of fine-tuning significantly supports T over NSU; this, however, neither shows that, everything considered, T is probably true, nor that it is the most plausible explanation of existence of the universe, nor even that it is more probable than NSU. In order to show that any hypothesis is likely to be true using a likelihood approach, we would have assess the prior epistemic probability of the hypothesis, something I shall not attempt to do for T.

Our more limited conclusion is nonetheless highly relevant to the rationality of and justification for belief in God, even though it does not itself establish that, all things considered, T is more probable than NSU. One could argue, for example, that in everyday life and science we speak of evidence for and against various views, but seldom of prior probabilities. For example, if one were to ask most physicists why they (tentatively) believe in General Relativity's approximate truth (or at least its future empirical fruitfulness), they probably would cite the evidence in favor of it, along with some of Einstein's motivations. They probably would not cast these considerations – such as Einstein's motivations – into talk of prior probability, either epistemic or otherwise. Of course, at the end of the day, some might say things such as "Einstein's theory is likely to be true," which is a notion of epistemic probability. But I can imagine them saying, "I have no idea what the prior probability of Einstein's theory is; all I will say is that Einstein had motivations for considering it and there are at least three strong pieces of empirical evidence in its favor." Indeed, I think it would be very difficult to estimate the prior probability of General Relativity's approximate truth (or future empirical fruitfulness) in any objective manner, since we should have to weigh incommensurable factors against each other – the simplicity of the mathematical framework of General Relativity against such things as the philosophically puzzling character of the idea of a four-dimensional space-time's being curved. Arguably, this is analogous to the case of T.

One way of putting my approach in perspective is to note that one of the most common philosophical objections to T is an updated version of one offered by Kant, in which the methods of theoretical reason are restricted to justifying only the existence of natural causes. Unlike Kant, however, modern atheistic philosophers often reject God as a necessary hypothesis of practical reasoning. Typically, these philosophers claim that by analyzing the notion of explanation, particularly as exemplified in natural science, we find that to explain something involves citing overarching laws, mechanical causes, and the like; thus, they assert, the very notion of explanation involves a restriction to purely naturalistic explanations. The idea of God as providing a complete explanation of all contingent reality is therefore rejected as being empty, an improper extension of the notion of "explain" to places where it cannot apply. Another attack is to argue that even if God could be said to explain contingent reality, God's own existence would be as much in need of explanation.

Richard Swinburne (2004, chaps. 2–4) has responded to these critics by offering an alternative analysis of ordinary explanation. He claims that these critics have neglected the notion of personal explanation and then goes on to claim that God provides the best personal explanation of everything we know about the universe. His argument rests on the dual claim that the simplicity of an explanation is the ultimate criterion of its adequacy and that God provides the simplest explanation of the universe. There are many places one might object to Swinburne's project, particularly these two claims about simplicity. Further, by basing his project on the notion of explanation used in everyday life, Swinburne leaves God's own existence entirely unexplained. Indeed, Swinburne claims that God is the ultimate contingent brute fact and could be said to necessarily exist only in the limited sense that God is without beginning and that, in principle, nothing could explain God's existence.

The approach I am taking avoids this question of how best to analyze the notion of explanation or whether God ultimately provides the best explanation of the universe. Rather, it simply attempts to establish the more limited claim that various features of the universe offer strong evidence in favor of T over its major naturalistic alternatives. I believe that establishing this more limited claim in a careful, principled way would alone be a great accomplishment. In Section 7.1, however, I address how this more limited claim fits into an overall argument for the existence of God. In that section, I also briefly address the issue of God's providing an ultimate explanation and respond to the claim that God is as much in need of a designer as the universe itself. A fuller discussion of this issue, however, is beyond the scope of this chapter.

1.4. Alternative version of argument: method of probabilistic tension

One problem with using simply the Likelihood Principle is that whether or not a hypothesis is confirmed or disconfirmed depends on what one builds into the hypothesis. For example, single-universe naturalists could prevent disconfirmation of their hypotheses by advocating *the elaborated naturalistic single-universe hypothesis* (NSUe), defined as NSU conjoined with the claim that the universe that exists is life-permitting: that is, NSUe = NSU & LPU. Similarly, theists could avoid any question about whether LPU is probable on T by constructing an elaborated theistic hypothesis (Te) which builds in the claim that God desired to create such a universe: Te = T & God desires to create a life-permitting universe.

One could attempt to deal with these sorts of moves by finding some principled way of restricting what can be built into the theistic and naturalistic hypotheses – for example, by requiring that the theistic and naturalistic hypotheses be some sort of "bare" theism and "bare" single-universe naturalism, respectively. This, however, is likely to run into difficulties not only in justifying the principle, but in defining what "bare" theism and "bare" single-universe naturalism are supposed to be. A simpler way of addressing the issue is by means of a concept I call *probabilistic tension*. A hypothesis h suffers from probabilistic tension if and only if h is logically equivalent to some conjunctive hypothesis, h_1 & h_2, such that $P(h_1|h_2) \ll 1$: that is, one conjunct of the hypothesis is very unlikely, conditioned on the other conjunct. Among other things, a hypothesis h that suffers from probabilistic tension will be very unlikely: since $P(h) = P(h_1 \,\&\, h_2) = P(h_1|h_2) \times P(h_2) = P(h_2|h_1) \times P(h_1)$, it follows that if $P(h_1|h_2) \ll 1$ or $P(h_2|h_1) \ll 1$, then $P(h) \ll 1$.

I claim that significant probabilistic tension is an epistemic black mark against a hypothesis, and thus offers us a reason to reject it. To see this, consider the fingerprint example discussed earlier. We noted that based on the Likelihood Principle, the matching of a defendant's fingerprints with those on a murder weapon often strongly confirms the guilt hypothesis over the innocence hypothesis. Such matching, however, does not confirm the guilt hypothesis over what could be called an "elaborated innocence hypothesis" – that is, an innocence hypothesis constructed in such a way that the matching of the fingerprints is implied by the hypothesis. An example of such a hypothesis is the claim that the defendant did not touch the murder weapon conjoined with the claim that someone else with almost identical fingerprints touched the weapon. This hypothesis entails that the fingerprints will appear to match, and hence by the Likelihood Principle the apparent matching could not confirm the guilt hypothesis over this hypothesis.

Nonetheless, this elaborated innocence hypothesis suffers from severe probabilistic tension: one conjunct of the hypothesis (that some other person with almost identical fingerprints touched the weapon) is very improbable on the other conjunct (that the defendant is innocent) since it is extremely rare for two people to happen to have almost identical fingerprints. Given that the guilt hypothesis does not suffer from a corresponding probabilistic tension, the high degree of probabilistic tension of the elaborated innocence hypothesis gives us strong reason to reject it over the guilt hypothesis, even though this elaborated hypothesis is not itself disconfirmed by the matching of the fingerprints.

This idea of probabilistic tension allows us to eliminate any arbitrariness with regard to how we choose the theistic and naturalistic hypotheses that we are confirming or disconfirming.[5] For example, both the theist and the naturalist can build into their respective hypotheses whatever is necessary for them to entail the relevant data. Then one can apply the method of probabilistic tension to these elaborated hypotheses. Consider, for instance, the NSUe and the Te defined earlier: that is, NSUe = NSU & LPU and Te = T & God desires to create a life-permitting universe. Both of these hypotheses entail LPU, and hence neither is confirmed (via the Likelihood Principle) with respect to the other by LPU.

Now given the truth of Premise (1) of our main argument in Section 1.3, NSUe clearly exhibits a high degree of probabilistic tension relative to background information k′, since one conjunction of the hypothesis, LPU, is very improbable conditioned on the other conjunct, NSU: that is, $P(LPU|NSU \& k') \ll 1$.[6] Given the truth of Premise (2), elaborated theism will not suffer any corresponding probabilistic tension. The reason is that according to Premise (2), it is not the case that $P(LPU|T \& k') \ll 1$, and hence it follows that it is *not* unlikely that the God of "bare theism" would desire to create a life-permitting universe. This means there will be no probabilistic tension between "bare" theism and the claim that God desires to create such a universe. This will be true even if the probability of $P(LPU|T \& k')$ is merely indeterminate, since such a probabilistic tension would exist only if $P(LPU|T \& k') \ll 1$. Thus, the fine-tuning evidence causes NSUe to suffer from a severe probabilistic tension without causing a corresponding probabilistic tension in Te. Thus, because it creates this probabilistic tension, we could say that the fine-tuning evidence (but not LPU itself) gives us strong reason to reject NSUe over Te.

In practice, any sufficiently elaborated hypothesis will suffer from severe probabilistic tension somewhere. For instance, the elaborated guilt hypothesis mentioned earlier could

5. Later, in Section 4.3, we shall see that the method of probabilistic tension also helps eliminate a potential arbitrariness problem that arises with the choice of the appropriate background information k′.

6. This probabilistic tension, of course, makes NSUe very unlikely. Since $P(LPU|NSU \& k') \ll 1$ and $P(LPU\&NSU) = P(LPU|NSU) \times P(NSU)$, it follows that $P(NSUe) = P(NSU \& LPU) \ll 1$. One cannot conclude, however, that NSUe is less likely than Te, unless one can determine various prior probabilities, which I am avoiding doing.

include that the knife used in the murder was green, had a certain shaped scratch mark on its handle, had a weight of 0.15679876675876 kg, and the like. The corresponding elaborated innocence hypothesis would include the same data. Both would suffer from severe probabilistic tension with respect to each piece of data – for example, the murder knife having a weight of 0.15679876675876 kg is very improbable under both the "bare" guilt and "bare" innocence hypothesis. The lesson here is that only the probabilistic tension which one hypothesis has and which another lacks relative to some specified domain can be used as evidence in favor of one hypothesis over another. In our case, the relevant specified domain causing probabilistic tension is that of the fine-tuning data. Elaborated naturalism might do better in other areas with regard to probabilistic tension, but to say that the fine-tuning data counts against elaborated naturalism with respect to elaborated theism, all we have to show is that the fine-tuning evidence creates a probabilistic tension within elaborated naturalism without creating a corresponding tension within elaborated theism.

2. The Evidence for Fine-Tuning

2.1. Introduction

The evidence for fine-tuning of the universe for life falls into three categories:

(i) The fine-tuning of the laws of nature.
(ii) The fine-tuning of the constants of nature.
(iii) The fine-tuning of the initial conditions of the universe.

We shall present examples of each type of fine-tuning further in the discussion. Before we begin, we should note that each of the aforementioned types of fine-tuning presupposes that a necessary requirement for the evolution of embodied moral agents is that there exist material systems that can sustain a high level of self-reproducing complexity – something comparable to that of a human brain. Given what we know of life on Earth, this seems a reasonable assumption.

2.2. Laws of nature

The first major type of fine-tuning is that of the laws of nature. The laws and principles of nature themselves have just the right form to allow for the existence embodied moral agents. To illustrate this, we shall consider the following five laws or principles (or causal powers) and show that if any one of them did not exist, self-reproducing, highly complex material systems could not exist: (1) a universal attractive force, such as gravity; (2) a force relevantly similar to that of the strong nuclear force, which binds protons and neutrons together in the nucleus; (3) a force relevantly similar to that of the electromagnetic force; (4) Bohr's Quantization Rule or something similar; (5) the Pauli Exclusion Principle.

If any one of these laws or principles did not exist (and were not replaced by a law or principle that served the same or similar role), complex self-reproducing material systems could not evolve. First, consider gravity. Gravity is a long-range attractive force between all material objects, whose strength increases in proportion to the masses of the objects and falls off with the inverse square of the distance between them. In classical physics, the amount of force is given by Newton's law, $F = Gm_1m_2/r^2$, where F is the force of attraction between two masses, m_1 and m_2, separated by a distance r, and G is the gravitational constant (which is simply a number with a value of $6.672 \times 10^{-11}\ \mathrm{N{\cdot}m^2/kg^2}$). Now consider what would happen if there were no universal, long-range attractive force between material objects, but all the other fundamental laws remained (as much as possible) the same. If no such force existed, then there would be no stars, since the force of gravity is what holds the matter in stars together against the outward forces caused by the high internal temperatures inside the stars. This means that there would be no long-term energy sources to sustain the evolution (or even existence) of highly complex life. Moreover, there probably would be no planets, since there would be nothing to bring material particles together, and even if there were planets (say because planet-sized objects always existed in the universe and were held together by cohesion), any beings of significant size could not move around without floating off the planet with no way of returning. This means that embodied moral agents could not evolve, since the development of the brain of such beings would require significant mobility. For all these reasons, a universal attractive force such as gravity is required for embodied moral agents.

Second, consider the strong nuclear force. The strong nuclear force is the force that binds nucleons (i.e. protons and neutrons) together in the nucleus of an atom. Without it, the nucleons would not stay together. It is actually a result of a deeper force, the "gluonic force," between the quark constituents of the neutrons and protons, a force described by the theory of quantum chromodynamics. It must be strong enough to overcome the repulsive electromagnetic force between the protons and the quantum zero-point energy of the nucleons. Because of this, it must be considerably stronger than the electromagnetic force; otherwise the nucleus would come apart. Further, to keep atoms of limited size, it must be very short range – which means its strength must fall off much, much more rapidly than the inverse square law characteristic of the electromagnetic force and gravity. Since it is a purely attractive force (except at extraordinarily small distances), if it fell off by an inverse square law like gravity or electromagnetism, it would act just like gravity and pull all the protons and neutrons in the entire universe together. In fact, given its current strength, around 10^{40} stronger than the force of gravity between the nucleons in a nucleus, the universe would most likely consist of a giant black hole.

Thus, to have atoms with an atomic number greater than that of hydrogen, there must be a force that plays the same role as the strong nuclear force – that is, one that is much stronger than the electromagnetic force but only acts over a very short range. It should be clear that embodied moral agents could not be formed from mere hydrogen, contrary to what one might see on science fiction shows such as *Star Trek*. One cannot obtain enough self-reproducing, stable complexity. Furthermore, in a universe in which no other atoms but hydrogen could exist, stars could not be powered by nuclear fusion, but only by gravitational collapse, thereby drastically ~~decrease~~ the time for, and hence probability of, the evolution of embodied moral agents.

Third, consider electromagnetism. Without electromagnetism, there would be no atoms, since there would be nothing to hold the electrons in orbit. Further, there would be no means of transmission of energy from stars for the existence of life on planets. It is doubtful whether enough stable complexity could arise in such a universe for even the simplest forms of life to exist.

Fourth, consider Bohr's rule of quantization, first proposed in 1913, which requires that electrons occupy only fixed orbitals (energy levels) in atoms. It was only with the development of quantum mechanics in the 1920s and 1930s that Bohr's proposal was given an adequate theoretical foundation. If we view the atom from the perspective of classical Newtonian mechanics, an electron should be able to go in any orbit around the nucleus. The reason is the same as why planets in the solar system can be any distance from the Sun – for example, the Earth could have been 150 million miles from the Sun instead of its present 93 million miles. Now the laws of electromagnetism – that is, Maxwell's equations – require that any charged particle that is accelerating emit radiation. Consequently, because electrons orbiting the nucleus are accelerating – since their direction of motion is changing – they would emit radiation. This emission would in turn cause the electrons to lose energy, causing their orbits to decay so rapidly that atoms could not exist for more than a few moments. This was a major problem confronting Rutherford's model of the atom – in which the atom had a nucleus with electrons around the nucleus – until Niels Bohr proposed his *ad hoc* rule of quantization in 1913, which required that electrons occupy fixed orbitals. Thus, without the existence of this rule of quantization – or something relevantly similar – atoms could not exist, and hence there would be no life.

Finally, consider the Pauli Exclusion Principle, which dictates that no two fermions (spin-½ particles) can occupy the same quantum state. This arises from a deep principle in quantum mechanics which requires that the joint wave function of a system of fermions be antisymmetric. This implies that not more than two electrons can occupy the same orbital in an atom, since a single orbital consists of two possible quantum states (or more precisely, eigenstates) corresponding to the spin pointing in one direction and the spin pointing in the opposite direction. This allows for complex chemistry, since without this principle, all electrons would occupy the lowest atomic orbital. Thus, without this principle, no complex life would be possible.[7]

2.3. Constants of physics

2.3.1. Introduction

The constants of physics are fundamental numbers that, when plugged into the laws of physics, determine the basic structure of the universe. An example of a fundamental constant is Newton's gravitational constant G, which determines the strength of gravity via Newton's law $F = Gm_1m_2/r^2$. We will say that a constant is fine-tuned if the width of its life-permitting range, W_r, is very small in comparison to the width, W_R, of some properly chosen comparison range: that is, $W_r/W_R \ll 1$. A more philosophically rigorous way of determining this comparison range will be presented in Section 4.4. Here we shall simply use certain standard comparison ranges that naturally arise in physics and hence are used by physicists when they speak of cases of anthropic fine-tuning.[8]

7. The Pauli Exclusion Principle also applies to the nucleus. It prevents an indefinite number of neutrons from falling into the lowest nuclear shell, thereby putting a limit on the atomic weight of atoms, a limit which appears necessary for life.

8. Physicists often speak of a requirement that there be "no fine-tuning" in a way that is independent of considerations regarding the existence of life. Two versions of this requirement are (i) that "all dimensionless parameters should be of the order of unity" (Narkilar 2002, pp. 479–80), and (ii) that the value of a constant should not be much, much smaller than the quantum corrections to its bare value, since otherwise the bare value

There are many examples of the anthropic fine-tuning of the fundamental constants of physics. Elsewhere, I have more thoroughly examined six of what I considered the most well-established cases, carefully articulating the physical lines of evidence offered in support of these cases along with correcting some incorrect and often-repeated claims regarding fine-tuning (Collins 2003). For purposes of illustration, here I shall explicate in some detail only two constants of physics – the strength of gravity and the cosmological constant.[9]

2.3.2. Fine-tuning of gravity

Using a standard measure of force strengths – which turns out to be roughly the relative strength of the various forces between two protons in a nucleus – gravity is the weakest of the forces, and the strong nuclear force is the strongest, being a factor of 10^{40} – or 10 thousand billion, billion, billion, billion times stronger than gravity (Barrow & Tipler 1986, pp. 293–5). Now if we increased the strength of gravity a billionfold, for instance, the force of gravity on a planet with the mass and size of the Earth would be so great that organisms anywhere near the size of human beings, whether land-based or aquatic, would be crushed. (The strength of materials depends on the electromagnetic force via the fine-structure constant, which would not be affected by a change in gravity.) Even a much smaller planet of only 40 ft in diameter – which is not large enough to sustain organisms of our size – would have a gravitational pull of 1,000 times that of Earth, still too strong for organisms with brains of our size to exist. As astrophysicist Martin Rees notes, “In an imaginary strong gravity world, even insects would need thick legs to support them, and no animals could get much larger” (2000, p. 30). Based on the evidence from Earth, only organisms with brains of a size comparable to our own have significant moral agency. Consequently, such an increase in the strength of gravity would render the existence of embodied moral agents virtually impossible and thus would not be life-permitting in the sense that we defined.

Of course, a billionfold increase in the strength of gravity is a lot, but compared with the total range of the strengths of the forces in nature (which span a range of 10^{40}), it is very small, being one part in 10 thousand, billion, billion, billion. Indeed, other calculations show that stars with lifetimes of more than a billion years, as compared with our Sun’s lifetime of 10 billion years, could not exist if gravity were increased by more than a factor of 3,000 (Collins 2003). This would significantly inhibit the occurrence of embodied moral agents.

would have to be fine-tuned to be almost exactly opposite of the quantum correction to yield such a relatively small value for the constant (see Donoghue 2007, pp. 234–6). It is important, therefore, not to naively equate discussions of fine-tuning in the physics literature with anthropic fine-tuning, although, as John Donoghue (2007) shows, they are often closely related.

9. Some other examples of fine-tuning of the constants are the following: if the mass of the neutron were slightly increased by about one part in 700, stable hydrogen burning stars would cease to exist (Leslie 1989, pp. 39–40; Collins 2003); if the weak force were slightly weaker by one part in 10^9 of the range of force strengths, then the existence of complex life would be severely inhibited (Collins 2003); finally, if the “vacuum expectation value” of the Higgs field were not within a few times its present strength, complex atoms (with atomic numbers greater than hydrogen) could not exist (see Donoghue 2007, pp. 237–8). All these cases, however, need more explication and analysis than can be given here.

The case of fine-tuning of gravity described is relative to the strength of the electromagnetic force, since it is this force that determines the strength of materials – for example, how much weight an insect leg can hold; it is also indirectly relative to other constants – such as the speed of light, the electron and proton mass, and the like – which help determine the properties of matter. There is, however, a fine-tuning of gravity relative to other parameters. One of these is the fine-tuning of gravity relative to the density of ~~matter~~ in the early universe and other factors determining the expansion rate of the Big Bang – such as the value of the Hubble constant~~, the density of radiation energy,~~ and the value of the cosmological constant. Holding these other parameters constant, if the strength of gravity were smaller or larger by an estimated one part in 10^{60} of its current value, the universe would have either exploded too quickly for galaxies and stars to form, or collapsed back on itself too quickly for life to evolve.[10] The lesson here is that a single parameter, such as gravity, participates in several different fine-tunings relative to other parameters.

2.3.3. The cosmological constant

Probably the most widely discussed case of fine-tuning for life is that of the cosmological constant. The cosmological constant, Λ, is a term in Einstein's equation of General Relativity that, when positive, acts as a repulsive force, causing space to expand and, when negative, acts as an attractive force, causing space to contract. Einstein's equation implies that if the vacuum – that is, space-time devoid of normal matter – has an energy density, then that energy density must act in a mathematically, and hence physically, equivalent way to a cosmological constant. The seeming need for fine-tuning of the cosmological constant arises from the fact that almost every field within modern physics – the electromagnetic field, the Higgs fields associated with the weak force, the *inflaton* field hypothesized by inflationary cosmology, the *dilaton* field hypothesized by superstring theory, and the fields associated with elementary particles – each contributes to the vacuum energy far in excess of the maximum life-permitting amount. These contributions to the vacuum energy can be either negative or positive. If the total effective cosmological constant is positive and larger than some positive value $\Lambda+_{max}$, or negative and smaller than some negative value $\Lambda-_{max}$, then the universe would have expanded (if positive), or collapsed (if negative), too quickly for stars or galaxies to form. Thus, for life to occur, the cosmological constant must be between $\Lambda-_{max}$ and $\Lambda+_{max}$. I shall let Λ_{max} designate the larger of the two absolute values of $\Lambda-_{max}$ and $\Lambda+_{max}$. Since the absolute values of $\Lambda-_{max}$ and $\Lambda+_{max}$ are within one or two orders of magnitude of each other, I shall explain the cosmological constant problem for the case in which Λ is assumed to be positive, but the same analysis will apply for the case in which Λ is negative.

10. This latter fine-tuning of the strength of gravity is typically expressed as the claim that the density of matter at the Plank time (the time at which we have any confidence in the theory of Big Bang dynamics) must have been tuned to one part in 10^{60} of the so-called critical density (e.g. Davies 1982, p. 89). Since the critical density is inversely proportional to the strength of gravity (Davies 1982, p. 88, eqn. 4.15), the fine-tuning of the matter density can easily be shown to be equivalent to the aforementioned claim about the tuning of the strength of gravity. Of course, if one cites this fine-tuning of gravity, one cannot then treat the fine-tuning of the force of the Big Bang or matter density of the Big Bang as an independent fine-tuning. (See Section 5.1.2 for how to combine cases of fine-tuning.)

Einstein originally hypothesized the existence of the cosmological constant so that his theory would imply a static universe. Thus, the original cosmological constant that Einstein postulated was not associated with contributions to the vacuum energy of the various fields of physics. If we let Λ_{vac} represent the contribution to the cosmological constant from the vacuum energy of all the fields combined, and Λ_{bare} represent the intrinsic value of the cosmological constant apart from any contribution from these fields, then the total value, Λ_{tot}, of the cosmological constant is $\Lambda_{tot} = \Lambda_{vac} + \Lambda_{bare}$. The contributions to Λ_{vac} can be further divided into those contributions arising from various forms of potential energy, V, as the universe passes through different phases along with those arising from the zero-point energies of the vacuum fluctuations of the quantum fields of the fundamental forces and elementary particles.

Finally, there have been various proposals for a new and highly speculative type of energy, called *quintessence*, whose defining feature is that it acts like a cosmological constant in the way it causes space to expand or contract, but unlike the cosmological constant it can change with time as the universe evolves from the Big Bang onward. Consequently, we can define the total *effective* cosmological constant as the sum of all these contributions that *function in the same way* as the cosmological constant with regard to causing space to expand or contract: that is, $\Lambda_{eff} = \Lambda_{vac} + \Lambda_{bare} + \Lambda_q$, where Λ_q designates the contribution resulting from quintessence. *The fine-tuning problem can now be stated as follows: without fine-tuning or some new principle of physics,* Λ_{eff} *is expected to be at least* 10^{53} *to* 10^{120} *times larger than the maximum life-permitting value* Λ_{max}. The smallness of the cosmological constant compared to its non-fine-tuned, theoretically expected value is widely regarded as the single greatest problem confronting current physics and cosmology.

To understand this fine-tuning problem more fully, it will be helpful to consider the three major types of contribution to the vacuum energy term, Λ_{vac}, of the cosmological constant in modern cosmology. Following standard terminology, we will let ρ_{vac} designate the vacuum energy density, and ρ_{max} the maximum vacuum energy density compatible with the existence of life, given that the vacuum energy is the only contribution to the cosmological constant.[11] The first contribution we shall consider arises from the Higgs field postulated as part of the widely accepted Weinberg–Salem–Glashow electroweak theory. According to this theory, the electromagnetic force and the weak force acted as one force prior to symmetry breaking of the Higgs field in the very early universe when temperatures were still extremely high. Before symmetry breaking, the vacuum energy of the Higgs field had its maximum value V_0. This value was approximately 10^{53} ρ_{max}. After symmetry breaking, the Higgs field fell into some local minimum of its possible energy density, a minimum which theoretically could be anywhere from zero to 10^{53} ρ_{max}, being solely determined by V_0 and other free parameters of the electroweak theory.[12]

Now either this local minimum is less than ρ_{max}, or it is greater than ρ_{max} and the other contributions to the cosmological constant offset its contribution to Λ_{eff} so that $\Lambda_{eff} < \Lambda_{max}$. In either case, the fine-tuning would have to be in one part in 10^{53}. In the former case, for instance, the local minimum of energy would have to be between zero and ρ_{max}, which would be one part in 10^{53} of its possible range of values.

11. Choosing units in which the speed of light, c, is equal to one (as is commonly done), it follows from Einstein's equation that $\rho_{vac} = 8\pi G\Lambda_{vac}$ and $\rho_{max} = 8\pi G\Lambda_{max}$, where G is Newton's constant of gravity. Hence, the vacuum energy and the cosmological constant are strictly proportional to each other.

12. See Collins (2003, p. 196, endnote 9) for more analysis of this case.

The second contribution to the vacuum energy is the postulated inflaton field of inflationary cosmology. Inflationary universe models hypothesize that the inflaton field had an enormously high energy density in the first 10^{-35} to 10^{-37} seconds of our universe, resulting in an effective cosmological constant that caused space to expand by a factor of around 10^{60} (Guth 1997, p. 185). By around 10^{-35} seconds or so, however, the value of the inflaton field fell to a relatively small value corresponding to a *local minimum* of its energy.[13] Now, in order to start inflation, the initial energy density of the inflaton field, ρ_i, must have been enormously larger than ρ_{max}: $\rho_i >> \rho_{max}$. Theoretically, however, the local minimum of the inflaton field could be anything from zero to ρ_i (see Sahni & Starobinsky 1999, sec. 7.0; Rees 2000, p. 154). The fact that the effective cosmological constant after inflation is less than ρ_{max} requires an enormous degree of fine-tuning, for the same reason as the Higgs field mentioned – for example, neglecting other contributions to the cosmological constant, the local minimum of energy into which the inflaton field fell must be between zero and ρ_{max}, a tiny portion of the its possible range, zero to ρ_i.

The final contribution results from the so-called *zero-point energies* of the fields associated with forces and elementary particles, such as the electromagnetic force and electrons and protons. If we calculate this contribution using quantum field theory and assume that space is a continuum, the contribution turns out to be infinite. Physicists, however, typically assume that quantum field theory is valid only up to a certain very large cutoff energy (see Section 4.5), in which case the contribution turns out to be extraordinarily large, but finite, with the actual value depending on the cutoff energy below which quantum field theory is taken as valid. The so-called Plank energy is often assumed to be the energy scale that quantum field theory breaks down, in which case the energy contribution of the zero-point energy for the various fields would be expected to be $10^{120}\ \rho_{max}$ (see Sahni & Starobinsky 1999, p. 44). To reduce this contribution to within an order of magnitude of the life-permitting range (thus eliminating any significant fine-tuning) would require an extremely low cutoff energy, which most physicists consider very unlikely (Donoghue 2007, p. 236).

One solution to the cosmological constant problem is to claim that God, or some other intelligence, fine-tuned the various contributions to the cosmological constant, $\Lambda_{vac} + \Lambda_{bare} + \Lambda_q$, in such a way that $\Lambda_{eff} < \Lambda_{max}$. Another much discussed solution is an appeal to multiple universes and some anthropic selection effect, which we shall discuss in Section 6. Is there a nondivine, nonanthropic solution to the fine-tuning of the cosmological constant? Physicist Victor Stenger, the leading critic of the data appealed to by advocates of the fine-tuning argument, claims that there is. According to Stenger:

> . . . recent theoretical work has offered a plausible non-divine solution to the cosmological constant problem. Theoretical physicists have proposed models in which the dark energy is not identified with the energy of curved space-time but rather with a dynamical, material energy field called *quintessence*. In these models, the cosmological constant is exactly 0, as suggested by a symmetry principle called *supersymmetry*. Since 0 multiplied by 10^{120} is still 0, we have no cosmological constant problem in this case. The energy density of quintessence is not constant but evolves along with the other matter/energy fields of the universe. Unlike the cosmological constant, quintessence energy density need not be fine-tuned. (2004, p. 182)

13. Although the Higgs fields and the other fields of physics could contribute to inflation, for various technical reasons inflationary cosmology requires a distinct energy field that helps create a very large effective cosmological constant in the very early universe. There is currently no candidate for this field that is "deeply rooted in well-established theories of fundamental physics" (Albrecht 2004, p. 381).

Although in a later publication, Stenger (2007, pp. 151–3) does not mention supersymmetry, he still claims that a hypothesized new form of energy, quintessence, could solve the cosmological constant problem and that it "requires no fine-tuning" (Stenger 2007, p. 152).

Stenger's proposal can be summarized in three steps: (1) postulate some natural symmetry or principle that requires that the cosmological constant, $\Lambda_{tot} = \Lambda_{vac} + \Lambda_{bare}$, be zero; (2) postulate some additional quintessential field to account for what appears to be a small positive value of the *effective* cosmological constant today;[14] and (3) postulate that there is some natural equation that implies that $\Lambda_q < \Lambda_{max}$ in the early universe, an equation which itself does not require fine-tuning. Since $\Lambda_{eff} = \Lambda_{vac} + \Lambda_{bare} + \Lambda_q$, those three steps would guarantee in a natural way that $\Lambda_{eff} < \Lambda_{max}$.

A well-known proposal that would go part way to making $\Lambda_{tot} = 0$ is the appeal to the speculative hypothesis of supersymmetry. Supersymmetry requires that for each bosonic field there exist a corresponding fermionic field, where bosonic fields are those associated with spin-1 particles, such as the photon, and fermionic fields are those associated with spin-½ particles, such as electrons and protons. It further requires that the positive zero-point energy contribution associated with each bosonic field is exactly canceled by the negative zero-point energy contribution associated with the corresponding fermionic field. Consequently, it requires that the total zero-point energies associated with the various fields of physics sum to zero, resulting in a net contribution of zero to the total cosmological constant. This solution faces a major difficulty: even if supersymmetry exists, it is presently a broken symmetry and thus cannot solve the cosmological constant problem. As astrophysicist John Peacock notes, "supersymmetry, if it exists at all, is clearly a broken symmetry at present day energies; there is no natural way of achieving this breaking while retaining the attractive consequence of a zero cosmological constant, and so the Λ problem remains as puzzling as ever" (1999, p. 268).

Further, even if some other symmetry could be discovered that would force the contributions of the bosonic or fermionic fields to cancel each other out, the first two contributions to the cosmological constant mentioned earlier would remain – that is, those arising from the Higgs field and the inflaton field. In order to get a zero cosmological constant, one would have to postulate some law, symmetry, or other mechanism that forced the sum of *all* contributions to the cosmological constant to be zero. In order to get this suggestion to work, physicists would have to either (a) abandon inflationary cosmology, which requires that the effective cosmological constant be initially very large and then fall off to near zero, or (b) invoke some special law, symmetry, or "mechanism" that selectively requires that the cosmological constant be zero at the end of the inflationary period. If options (a) and

14. The assumption that $\Lambda_{eff} > 0$ is regarded by most physicists as the best way of accounting for the evidence, based on redshifted light from distant supernovae, that the universe is accelerating. An effective cosmological constant is not the only way of explaining the cosmic acceleration, however. Olga Mena and José Santiago (2006) have recently developed a modification of Einstein's theory of gravity that explains the acceleration of the universe without appealing to an effective cosmological constant. Their model, however, still must assume some nonmaterial substance in addition to normal matter. As stated in their abstract, "the inverse-curvature gravity models considered *cannot* explain the dynamics of the Universe just with a baryonic matter component." If a successful non-*ad hoc* and non-fine-tuned modification of General Relativity could be developed that would account for the acceleration of the universe, it could serve as an alternative to steps (2) and (3) in an attempt to avoid the fine-tuning of the cosmological constant.

(b) are both rejected, one will be left with the fine-tuning problem generated by a large effective cosmological constant required for inflation that must drop off to near zero after inflation in order for life to exist.

Further, supposing that option (a) or (b) are chosen, steps (2) and (3) are still required to account for the small, nonzero effective cosmological constant today. In typical models of quintessence, Λ_q "tracks" the matter and radiation density of the universe – that is, Λ_q is some function of these densities. One problem here is that unless the function is both natural and simple, without any adjustable parameters needed to make $\Lambda_q < \Lambda_{max}$, the problem of fine-tuning will simply re-arise: if that function is not simple or natural, or such a parameter is needed, then the question will arise as to why that function or parameter is such that the value of the effective cosmological constant is within the life-permitting range instead of falling outside the life-permitting range. So far, no such natural function has been found, and it is widely argued that current models of quintessence require fine-tuning, especially when combined with inflationary cosmology.[15] Further, quintessential energy must have special characteristics to act as an effective cosmological constant. As noted by physicists Robert R. Caldwell and Paul J. Steinhardt (2000), "The simplest model proposes that the quintessence is a quantum field with a very long wavelength, approximately the size of the observable universe." The long wavelength of the field means that its energy is dominated by potential energy, which in turn allows for it to act as an effective cosmological constant.

In sum, it is conceivable that by postulating the right set of laws–symmetries–mechanisms, physicists will be able to explain the fine-tuning of the effective cosmological constant in a non-*ad hoc* way. Nonetheless, two points should be made. First, any such explanation will require the hypothesis of just the right set of laws. At best, this will merely transfer the fine-tuning of the cosmological constant to that of the laws of nature; even if those laws of nature are deemed "natural," one would still have to have the right set of laws to eliminate the fine-tuning of the cosmological constant. Consequently, other than eliminating the ability to quantify the degree of fine-tuning, it is unclear how much such a move undercuts the need for some anthropic explanation. Second, it is unclear at what point we should continue searching for such an explanation in terms of physical laws when no plausible candidates have been forthcoming in the last 20 years. Atheists such as Stenger claim that we should continue searching until we can be absolutely sure that no scientific explanation can be found. In Section 2.5.2, where I consider the "God of the gaps" objection, I argue that such a requirement begs the question against T.

Finally, one way of avoiding the fine-tuning of the cosmological constant is to claim that one day the current framework of modern physics will be superseded in such a way as to avoid the fine-tuning problem. For example, one could claim that Einstein's theory of General Relativity will be superseded by a future theory that retains the verified predictions of General Relativity but does not predict that vacuum energy will cause space to

15. For example, physicists Christopher Kolda and David H. Lyth note that "an alternative to a cosmological constant is quintessence, defined as a slowly-varying scalar field potential V(φ). . . . In contrast with ordinary inflation, quintessence seems to require extreme fine tuning of the potential V(φ″)" (1999, abstract). Further, as physicist Gabriela Barenboim notes, models that combine inflation and quintessence "require significant *ad hoc* tuning to simultaneously produce the features of inflation and quintessence" (2006, p. 1).

expand.[16] Or one could claim that this prediction is an artifact of General Relativity that is not to be taken realistically, in analogy to how most physicists reject waves that travel backward in time, even though such waves are one mathematically legitimate solution to the equations of electromagnetism. Such moves, however, will involve giving up inflationary cosmology or radically reformulating it (since it depends on this prediction of General Relativity), and they would present difficulties for explaining the compelling evidence that the expansion of the universe is accelerating. Further, such moves clearly will not work for the fine-tuning of other constants, since many of them depend on facts so basic that they certainly will not be superseded. For example, the fine-tuning of the strength of gravity, as discussed in Section 2.3.2, only depends on the fact that bodies with masses typical of planets and stars attract each other with a force approximately given by Newton's law, and that if the gravitational pull of a planet is too large, most organisms would be crushed. Thus, as a general strategy, this way circumventing the fine-tuning of the cosmological constant is of limited value.

2.4. Initial conditions of the universe

One other fundamental type of fine-tuning should be mentioned, that of the initial conditions of the universe. This refers to the fact that the initial distribution of mass-energy – as measured by entropy – must fall within an exceedingly narrow range for life to occur. Some aspects of these initial conditions are expressed by various cosmic parameters, such as the mass density of the early universe, the strength of the explosion of the Big Bang, the strength of the density perturbations that led to star formation, the ratio of radiation density to the density of normal matter, and the like. Various arguments have been made that each of these must be fine-tuned for life to occur (see e.g. Rees 2000; Davies 1982, chap. 4). Instead of focusing on these individual cases of fine-tuning, I shall focus on what is arguably the most outstanding special initial condition of our universe: its low entropy. According to Roger Penrose, one of Britain's leading theoretical physicists, "In order to produce a universe resembling the one in which we live, the Creator would have to aim for an absurdly tiny volume of the phase space of possible universes" (Penrose 1989, p. 343). How tiny is this volume? According to Penrose, if we let $x = 10^{123}$, the volume of phase space would be about $1/10^x$ of the entire volume (1989, p. 343). This is vastly smaller than the ratio of the volume of a proton – which is about 10^{-45} m^3 – to the entire volume of the visible universe, which is approximately 10^{84} m^3. Thus, this precision is much, much greater than the precision that would be required to hit an individual proton if the entire visible universe were a dartboard! Others have calculated the volume to be zero (Kiessling 2001).

Now phase space is the space that physicists use to measure the various possible configurations of mass-energy of a system. For a system of particles in classical mechanics, this phase space consists of a space whose coordinates are the positions and momenta (i.e. mass × velocity) of the particles, or any other so-called "conjugate" pair of position and momenta variables within the Hamiltonian formulation of mechanics. Consistency requires that any probability measure over this phase space remain invariant regardless of which conjugate positions and momenta are chosen; further, consistency requires

16. Apart from General Relativity, the absolute value of the energy has no physical consequences, only the relative differences in energy from one space-time point to another.

that the measure of a volume $V(t_0)$ of phase space at time t_0 be the same as the measure that this volume evolves into at time t, $V(t)$, given that the laws of physics are time-reversal invariant – that is, that they hold in the reverse time direction.[17] One measure that meets this condition is the standard "equiprobability measure" in which the regions of phase space are assigned a probability corresponding to their volume given by their position and momenta (or conjugate position and momenta) coordinates. Moreover, if an additional assumption is made – that the system is ergodic – it is the only measure that meets this condition.[18] This measure is called the *standard measure* of statistical mechanics, and forms the foundation for all the predictions of classical statistical mechanics. A related probability measure – an equiprobability distribution over the eigenstates of any quantum mechanical observable – forms the basis of quantum statistical mechanics.

Statistical mechanics could be thought of as the third main branch of physics, besides the theory of relativity and quantum theory, and has been enormously successful. Under the orthodox view presented in physics texts and widely accepted among philosophers of physics, it is claimed to explain the laws of thermodynamics, such as the second law, which holds that the entropy of a system will increase towards its maximum with overwhelming probability.

Applying this measure to the initial state of the universe, we could then say that under the standard measure, it is enormously improbable, having a probability equal to the minute portion of phase space compatible with it. Indeed, in discussions of the issue, it is typically assumed that this state is enormously improbable. The probability here is not the probability of the particles' (or fields') being in the exact microstate that they were in; that is always zero. Rather, it is the state specified by the requirement that the entropy be low enough for the occurrence of stars and ultimately life. An infinite number of microstates meet this requirement, but they all must be in that tiny region of phase space that Penrose mentions. Finally, it is important to note that the standard measure of statistical mechanics must imply a corresponding epistemic probability measure. The reason is that statistical mechanics is supposed to tell us what *to expect* a system's behavior to be. For instance, the calculation that an increase in entropy for a physical system in the next 5 minutes is enormously improbable leads us to be almost certain that it will not occur – that is, it generates a very low epistemic probability for its occurrence. Thus, applying the standard measure to the initial condition of our universe implies that it has an enormously low unconditional epistemic probability of occurring.

Many points could be disputed in the aforementioned argument and I cannot adequately enter into the debate here. Rather, I shall just summarize three of the major

17. The reason that the statistical mechanics measures are assumed to be time-invariant is easy to see, given that the laws of physics are deterministic and time-reversal invariant. Let $C(t_0)$ be some class of possible initial states of a system. Each member $m(t_0)$ of $C(t_0)$ will evolve into some particular state $m(t)$ at time t. Call $C(t)$ the class of all such states $m(t)$. If the laws of physics are time reversal invariant, any state $m^*(t) \in C(t)$ could have come from only one state $m^*(t_0) \in C(t_0)$ at time t_0. Thus, there is a one-to-one correspondence between microstates in $C(t_0)$ and microstates in $C(t)$. Consequently, if the probability of some system having a microstate in a class $C(t_0)$ is x%, then it must be the case that the probability of the system having a microstate in the corresponding class $C(t)$ of states at time t is x%.

18. An ergodic system is one in which in the limit as time goes to infinity, the average proportion of time a system spends in a given region of phase space with finite volume is the same as the standard equiprobability measure for that region.

ways to avoid assigning an extremely low epistemic probability to the initial state of the universe. First, as suggested by David Albert (2000, pp. 150–62), one could attempt to ground the standard probability measure of statistical mechanics in postulated indeterministic quantum processes that have just the right probability distribution to yield this measure. As Albert (2000, p. 160–1) recognizes, such a procedure would still require the postulation of an enormously special, low-entropy macroscopic state at the beginning of the universe but would not require that one postulate a probability measure over the states of its phase space. Second, one could simply restrict all statements of probability in statistical mechanics to statements of conditional probability, where the statement being conditioned on is that that the universe started out in this special macrostate of exceedingly low entropy. Then one could treat the measure over phase space as applying only to those scattered points in phase space consistent with this initial assumption. Doing this would recover all the predictions of statistical mechanics, although it might seem an arbitrary restriction imposed to avoid treating the initial state as improbable. Third, one could point out, as John Earman (2006) has, that no one has been able to develop an even near-adequate mathematical measure for the degrees of freedom of the gravitational field, which is thought to play an essential role in the low entropy of the initial state of the universe.

In light of these responses, how should we view the purported improbability of the initial state? First, we can point out that the improbability assigned by the standard measure is the same as the one that we should assign using the method outlined in Sections 3.3.2 and 3.3.3, in which we argue that scientific confirmation requires that we place an epistemic equiprobability measure over the natural variables in a theory. In statistical mechanics these natural variables turn out to be the position and momenta, or other conjugate variables, used to construct phase space. Thus, it demonstrates a certain consistency in the method we proposed for arriving at epistemic probabilities. Second, all these responses admit that the initial state is in some sense enormously special in some way, while denying the degree of "specialness" can be quantified or physically explained. This leaves us with a strong qualitative, although nonquantifiable, form of fine-tuning.

2.5. Stenger's objections

As mentioned when we discussed the fine-tuning of the cosmological constant, in the last 15 years Victor Stenger has emerged as one of the leading critics of the evidence for fine-tuning. In the next two subsections, we shall look at two of his objections.

2.5.1. Stenger's "Monkey God" objection

One major way in which Stenger has attempted to cast skepticism on fine-tuning arguments is by constructing a computer program that shows that random selections of the constants of physics generally produce viable, life-permitting stars. He calls his computer program "Monkey God." Based on his program, Stenger concludes that:

> No basis exists for assuming that a random universe would not have some kind of life. Calculations of the properties of universes having different physical constants than ours indicate that long-lived stars are not unusual, and thus most universes should have time for complex systems of some type to evolve. (2000, p. 50)

Stenger calculates the lifetime of stars using the equation $t_s = (\alpha^2/\alpha_G)\ (m_p/m_e)^2\ \hbar/(m_p c^2)^{-1}$, where α is the dimensionless electromagnetic interaction strength, α_G is the dimensionless gravitational binding energy, m_p is the mass of the proton, m_e is the mass of the electron, $\hbar$ is Plank's constant divided by 2π, and c is the speed of light.

Using this equation and a program that randomly selects values for the relevant parameters in the aforementioned equation, Stenger concludes that long-lived stars are not unusual among these randomly selected universes and takes this to count as evidence against claims of fine-tuning. The first criticism of his approach is that he does not address the question of whether these universes would have other life-inhibiting features relative to ours. For example, if one decreases the strength of the strong nuclear force by more than 50 percent (while keeping the electromagnetic force constant), carbon becomes unstable, and with a slightly greater decrease, no atoms with atomic number greater than hydrogen can exist (Barrow & Tipler 1986, pp. 326–7). This would make it virtually impossible for complex life forms to evolve. That Stenger ignores these other life-inhibiting features is clear from his equation for the lifetime of a star (which is unaffected by changes in the strong nuclear force, since none of the parameters he uses depends on this strength), and is also obvious from what he says elsewhere regarding his "Monkey God" calculations:

> I find that long-lived stars, which could make life more likely, will occur over a wide range of these parameters. . . . For example, if we take the electron and proton masses to be equal to their values in our universe, an electromagnetic force any stronger than its value in our universe will give a stellar lifetime of more than 680 million years. The strength of the strong interaction does not enter into this calculation. (Stenger 2004, pp. 179–80)

Obviously, if we increased the electromagnetic force by very much while keeping the strong interaction the same, the nuclei of atoms other than hydrogen would break apart due to the increased electromagnetic repulsion of the protons in the nuclei. In this case, there could be no nuclear fusion in stars, and hence no stars.

Second, the equation he uses is based on a simple star model of stellar evolution. The equation does not take into account the complexities of a stellar evolution, such as whether the energy transport from the center of the star to the surface is by convection or radiative diffusion. More importantly, it assumes that the star is made mostly of hydrogen, which would not be the case if the strong force were increased beyond a small amount (see Collins 2003, p. 192 and references therein); further, it does not take into account the effects on star stability of quantum degeneracy, which require much more sophisticated codes to take into account. No simple equation could incorporate these sorts of complexities. As I have shown elsewhere (Collins 2003, pp. 192–3), *using a simple star model*, one can increase the strength of gravity a million- or a billionfold, and still obtain stable, long-lived stars with around the same surface temperature as our Sun. When one takes into account quantum degeneracy effects, however, one can only increase the strength of gravity by around a thousandfold before significantly decreasing the lifetime of stars (Collins 2003, pp. 193–4). Presumably, if one also changed one of the other constants, one could increase the strength of gravity by more than 3,000-fold and still obtain a stable, long-lived star, since it would change when electron degeneracy kicks in. In sum, life-prohibiting effects related to stellar lifetimes and stability only come to light when one begins to consider the complexity of the physics involved in stellar evolution, something Stenger has not done.

2.5.2. Stenger's "God of the gaps" objection

Another common objection to the fine-tuning argument is that it is a variation of the "God of the gaps" argument, and so it should be rejected. Victor Stenger raises this objection with regard to the fine-tuning of the cosmological constant. According to Stenger:

> While quintessence may not turn out to provide the correct explanation for the cosmological constant problem, it demonstrates, if nothing else, that science is always hard at work trying to solve its puzzles within a materialistic framework. The assertion that God can be seen by virtue of his acts of cosmological fine-tuning, like intelligent design and earlier versions of the argument from design, is nothing more than another variation on the disreputable God-of-the gaps argument. These rely on the faint hope that scientists will never be able to find a natural explanation for one or more of the puzzles that currently have them scratching their heads and therefore will have to insert God as the explanation. As long as science can provide plausible scenarios for a fully material universe, even if those scenarios cannot be currently tested they are sufficient to refute the God of the gaps. (2004, p. 182)

Elsewhere, Stenger claims that one would be justified in invoking God only if "the phenomenon in question is not only currently scientifically inexplicable but can be shown to forever defy natural description" (2007, pp. 13–4). As he recognizes, this requirement of proof is exceptionally strong. Although he qualifies his assertion regarding God as a scientific hypothesis, the question that arises is the level of proof that we need regarding the nonexistence of a plausible scientific explanation before we are justified in invoking God as an explanation of the fine-tuning, regardless of whether it is considered a scientific or a metaphysical explanation.

To answer this latter question, we must consider the reasons for thinking that a "God of the gaps" sort of explanation is in principle something to be avoided. The reasons partly depend on whether one is a theist or an atheist; and if one is a theist, it will depend on how one understands the nature of divine action. Many theists will claim that ultimately we should avoid a God of the gaps explanation because it is bad theology. According to these theists, God would be greater if God created a material order that could function on its own without God's needing to intervene and fill various gaps. If these theists are correct, then for theological reasons one should strenuously avoid appealing to divine intervention in the natural order to explain phenomena that science has not yet explained and instead trust that God has created a material world with its own integrity. *Such theological reasons, however, will not apply to the structure of the cosmos itself – its basic laws, its initial conditions, and the values of its constants – since these do not require any intervention in the natural order.* Other theists, such as intelligent design theorists, will be even more lenient concerning those cases in which it is appropriate to invoke God as an explanation.

Of course, atheists who are fully committed to a naturalistic account of the cosmos will always claim that it is illegitimate to appeal to God, since God does not exist. In order for the God of the gaps objection to avoid begging the question against the theist, however, it has to be framed in such a way as to carry force even on theistic assumptions. Such an argument does carry force, at least on the assumption of many theists, when God or some other transcendent designer is invoked to explain, for instance, seemingly irreducibly complex biological systems, since in such cases it implies that nature lacks sufficient integrity to produce the systems on its own. Stenger and others have not shown that it carries any non-question-begging force for the case of the structure of the universe as a whole.

One might object to this response by claiming that the history of science provides independent grounds for rejecting any appeal to God to fill in the apparent gaps left by science. The failure of such appeals, however, can be explained as well by the theist as the naturalist: for example, many theists would claim that Newton's famous invocation of God to keep the planetary orbits stable implies a less than satisfactory picture of a constantly intervening God. The key question is how one inductively extrapolates from these historical incidences, and that all depends on one's background assumptions – that is, whether one is an atheist or a theist, and what kind of theist one is. In themselves, these incidences can tell us nothing about whether we can be justified in appealing to God for explaining the fine-tuning.

But what about the scientific strictures of methodological naturalism? These would be relevant only if the appeal to God were considered as a *scientific* explanation, something that I am not assuming. Rather, God should be considered a philosophical or metaphysical explanation of LPU. So where does this leave us with regard to the burden of proof? The advocate of the fine-tuning argument will only need to argue that it is unlikely that all the cases can be given a natural explanation that removes their epistemic improbability without transferring that improbability up one level. And as argued in Sections 6.3.1 and 7.2, even if the fine-tuning of the constants of physics can be explained in terms of some set of deeper physical laws, as hypothesized by the so-called "theory of everything" or by an inflationary multiverse, this would simply transfer the improbability up one level to the existence of these deeper laws.

2.6. Conclusion

There are many other cases of fine-tuning that I have not discussed, such as those extensively discussed by biochemist Michael Denton (1998). These latter consist of various higher-level features of the natural world, such as the many unique properties of carbon, oxygen, water, and the electromagnetic spectrum, that appear optimally adjusted for the existence of complex biochemical systems (Denton 1988, chaps 3–6, pp. 19–140). Presumably, these higher-level features of the universe are ultimately grounded in the laws, constants, and initial conditions of the universe. Nonetheless, they provide additional evidence that the fundamental structure of the universe is fine-tuned for life.

As illustrated by the case of Victor Stenger discussed earlier (Section 2.5), it should be pointed out that some physicists and scientists have been skeptical of some of the prominent cases of fine-tuning in the literature. As I have shown in detail elsewhere, in some cases this skepticism is warranted, but in other cases the physical arguments offered for fine-tuning are solid (see Collins 2003). Nonetheless, even if there are no cases of fine-tuning that are sufficiently established to be beyond doubt, the argument would still have significant force. As philosopher John Leslie has pointed out, "clues heaped upon clues can constitute weighty evidence despite doubts about each element in the pile" (1988, p. 300). This is especially true given that the clues in this case fall into a variety of distinct types – there are not only three distinct fundamental types of fine-tuning, but there are many distinct cases under each type. The only plausible response that a skeptic could give to the multitude of different cases of fine-tuning is to find one or two overarching reasons that would undercut almost all the cases of fine-tuning in a single stroke. Given the diversity of the cases of fine-tuning, it is very unlikely that this will happen. In any case, in Section 7.2, I will address one such attempt, an attempt I call the "more fundamental law" objection, according to which there might be some fundamental law (or principle) that entails all the cases of fine-tuning.

3. Epistemic Probability

3.1. The need for epistemic probability

According to atheist Keith Parsons:

> If atheism is correct, if the universe and its laws are all that is or ever has been, how can it be said that the universe, with all of its 'finely tuned' features, is in any relevant sense probable or improbable? *Ex Hypothesi* there are no antecedent conditions that could determine such a probability. Hence, if the universe is the ultimate brute fact, it is neither likely nor unlikely, probable nor improbable; it simply is.
>
> Further, even if the universe were somehow improbable, it is hard to see on the hypothesis of atheism how we could ever know this. If we were in the position to witness the birth of many worlds – some designed, some undesigned – then we might be in a position to say of any particular world that it had such-and-such a probability of existing undesigned. But we simply are not in such a position. We have absolutely no empirical basis for assigning probabilities to ultimate facts. (1990, p. 182)

Although commonly raised, Parson's objection is deeply mistaken. It fails to recognize a common, nonstatistical kind of probability that some philosophers have called *epistemic probability* and others have called *inductive probability* (e.g. Swinburne 2001, p. 62).[19] As Ian Hacking notes in his excellent study of the history of probability theory, the idea of probability was Janus-faced from its emergence in seventeenth-century Europe, with one side being the notion of statistical probability and the other side being the notion of epistemic probability:

> On the one side it [the conception of probability] is statistical, concerning itself with stochastic laws or chance processes. On the other side it is epistemological, dedicated to assessing reasonable degrees of belief in propositions quite devoid of statistical background. (Hacking 1975, p. 12)

So, for instance, when people say that the Thesis of Common Ancestry is probably true given the fossil and genetic evidence we currently have, they are clearly not talking about statistical probability, since this thesis is about a unique event in Earth's history. The same holds for any claim about the probable truth (or "empirical adequacy") of a scientific theory. In his treatise, *A Treatise on Probability* (1921), John Maynard Keynes further developed this conception, and there have been several recent attempts to provide a more precise account of this sort of probability (e.g. Swinburne 2001, chaps. 3 and 4; Plantinga 1993, chap. 9).

In conjunction with the Likelihood Principle, this sort of probability is extensively used in scientific confirmation. Consider, for example, the arguments typically offered in favor

19. Swinburne (2001, p. 68), for instance, reserves the term "epistemic probability" for inductive probability that takes into account human cognitive limitations. I will use it more broadly to refer to what Swinburne calls "inductive probability."

of the Thesis of Common Ancestry, continental drift theory, and the atomic hypothesis. The Thesis of Common Ancestry is commonly supported by claiming that a variety of features of the world – such as the structure of the tree of life – would not be improbable if this thesis is true, but would be very improbable under other contending, nonevolutionary hypotheses, such as special creation. Consider, for instance, the following quotation from evolutionary biologist and geneticist Edward Dodson, in which he summarizes the case for evolution, understood as the Thesis of Common Ancestry:

> All [pieces of evidence] concur in *suggesting* evolution with varying degrees of cogency, but most can be explained on other bases, albeit with some damage to the law of parsimony. The strongest evidence for evolution is the concurrence of so many *independent probabilities*. That such different disciplines as biochemistry and comparative anatomy, genetics and biogeography should all point toward the same conclusion is very difficult to attribute to coincidence. (1984, p. 68; italics added)

Similar lines of reasoning are given for accepting continental drift theory. For example, the similarity between the animal and plant life on Africa and South America millions of years ago was considered to provide significant support for continental drift theory. Why? Because it was judged very unlikely that this similarity would exist if continental drift theory were false, but not if it were true.

Finally, consider the use of epistemic probability in the confirmation of atomic theory. According to Wesley Salmon (1984, pp. 219–20), what finally convinced virtually all physical scientists by 1912 of the atomic hypothesis was the agreement of at least 13 independent determinations of Avogadro's number based on the assumption that atomic theory was correct.[20] For example, one method of determining Avogadro's number is through observations of Brownian motion, that is, the random motion of very small particles suspended in a liquid, a motion that was postulated to be caused by the unequal, random impact of the molecules in the liquid. From this motion and the kinetic theory of heat, one can calculate what the mass of each molecule must be in order to account for the observed motion, and then using that value one can obtain Avogadro's number.

The scientists reasoned that *if atomic theory were false, then such an agreement between thirteen different determinations of Avogadro's number would be exceedingly epistemically improbable* – in Salmon's words, an "utterly astonishing coincidence" (1984, p. 220). Indeed, if scientists had not judged the agreement to be exceedingly improbable if atomic theory were false, it is difficult to see why they would take it to count as strong evidence in its favor. On the other hand, the scientists reasoned, if atomic theory were true, such an agreement would be expected. Thus, by implicitly using the *Likelihood Principle*, they reasoned that these independent determinations of Avogadro's number strongly confirmed atomic theory.

It should be noted that one could not avoid this sort of reasoning simply by rejecting scientific realism, since even though antirealists reject the truth or approximate truth of certain types of well-confirmed hypotheses, they still accept them as being reliable bases for future explanations and predictions – that is, in Bas van Fraassen's (1980) terminology,

20. Avogadro's number = 6.02252×10^{23}. Avogadro's number is defined as the number of atoms in 12 grams of carbon 12 and by definition is equal to the number of elementary entities in one mole of any substance.

they accept them as being "empirically adequate." Consequently, instead of interpreting the confirming evidence as evidence for a hypothesis' truth, they accept it as evidence for the hypothesis' empirical adequacy. This means that insofar as realists need to appeal to epistemic probabilities to support the approximate truth of a theory, antirealists will need to appeal to those same probabilities in support of a theory's empirical adequacy – for example, antirealists would need to claim that it is highly improbable for the determinations of Avogadro's number to agree if atomic theory were not empirically adequate.

Since some of the probabilities in the aforementioned examples involve singular, nonrepeatable states of affairs, they are not based on statistical probabilities, nor arguably other non-epistemic probabilities. This is especially evident for the probabilities involved in the confirmation of atomic theory since some of them involve claims about probabilities conditioned on the underlying structure and laws of the universe being different – e.g. atoms not existing. Hence, they are not based on actual physical propensities, relative frequencies, or theoretical models of the universe's operation. They therefore cannot be grounded in theoretical, statistical, or physical probabilities. Similar things can be said about many other ~~similar~~ types of confirmation in science, such as the confirmation of quantum electrodynamics (QED) by its extraordinarily precise prediction of the gyromagnetic moment of the electron, which we shall discuss later in this chapter. Such cases, I contend, establish the widespread use of purely epistemic probabilities in scientific confirmation that are neither grounded in other types of probability nor in experience – e.g. the probabilities invoked in atomic theory clearly are not grounded in experience, since nothing like such an agreement had ever occurred before. We shall return to this in Sections 3.3.2 and 3.3.3 when I discuss the Principle of Indifference.

3.2. An account of epistemic probability

Having established the need for epistemic probability, we now turn to developing an account of it. Accounts of epistemic probability range from the so-called subjective theory to the logical theory. According to the subjective theory, epistemic probability amounts to nothing more than our purely subjective degree of belief in a claim with the only restriction on the rationality of our degrees of belief is that they obey the probability calculus and conform to our own personal inductive standards. In contrast, according to the logical theory, epistemic probability refers to some human-mind independent relation analogous to that of logical entailment. Despite its popularity, I shall say nothing more here about subjective theory, other than that it seems to lead to an extreme form of epistemic relativism. The reason is that it does not distinguish between rational and irrational inductive criteria. Given the right inductive criteria almost any set of beliefs can be made to cohere with the probability calculus – for example, the belief that the Sun and stars revolve around the Earth can be made to cohere with all the current evidence we have to the contrary. (For a further critique, see Swinburne (2001, pp. 73f) and Plantinga (1993, pp. 143f)).

On the other hand, at least two major problems confront the purely logical theory of epistemic probability. First, it is doubtful that we need to hypothesize a metaphysics of human-mind independent relations of logical probability between propositions to ground the rationality of all of our statements involving epistemic probability. As Keynes (1921, pp. 4, 32) pointed out, all we need is the existence of relations of rational support or expectation that are independent of merely personal or cultural beliefs and standards. Consequently, allowing for the relations of epistemic probability to be dependent on the contingent construction of human cognitive faculties fits much better with my overall approach of trying to stay as close as possible to the principles of reasoning that are part of everyday and scientific practice (see Section 1.1).

Second, purely logical probability would guide the expectations only of logically omniscient agents – that is, agents that could see all logical relations between propositions, including the relations of logical probability. Humans, however, are limited to a partial grasp of such relations, which is reflected in the relevant usage of epistemic probability in science. For example, as Swinburne acknowledges, based on the current mathematical evidence, Goldbach's conjecture (that every even number greater than two is the sum of two prime numbers) is probably true, but not certainly true. That is, the current evidence – such as that Goldbach's conjecture has been shown to be true for the first trillion numbers and was claimed to be proven by some otherwise truthful mathematician – supports this conjecture, but not enough to justify our being certain that it is true. Since it is a mathematical claim, however, Goldbach's conjecture is either necessarily true, or it is necessarily false, and thus its logical probability is either one or zero. The epistemic probability being invoked here, therefore, is not purely logical probability. Even if one does not agree that this sort of epistemic probability arises in mathematics, nonetheless it is clear that when judging the evidential support for a scientific theory, we are not aware of all the relevant logical relations between the evidence and the theory. Keynes, who made the degree of logical/epistemological probability of one proposition on another relative to human powers, recognized this issue. According to him:

> If we do not take this view of probability, if we do not limit it in this way and make it, to this extent, relative to human powers, we are altogether adrift in the unknown; for we cannot ever know what degree of probability would be justified by the perception of logical relations which we are, and must always be, incapable of comprehending. (1921, p. 33)

Following Swinburne, one could still attempt to take logical probability as the primary kind of epistemic (or what he calls *inductive*) probability, and then attempt to accommodate human limitations. The problem with this approach is that in order to use logical probability to make statements about the rational degree of credence one ought to place in a theory, or the amount by which we should take a body of evidence to increase our confidence in a theory, one would need some account of how to translate degrees of logical probability to rational degrees of credence for beings subject to our limitations. Consequently, one would still need an account of another more human-centered type of epistemic probability that is relative to human cognitive powers to grasp these human perceptions of logical probability; in itself, logical probability only stipulates what the rational degrees of belief of a logically omniscient agent ought to be, not that of a mere human being. As far as I know, Swinburne does not provide any account that links the two together.

I call the conception of epistemic probability that is grounded in our perceptions of logical relations between propositions, *episto-logical* probability. In contrast to the episto-logical account of epistemic probability, Alvin Plantinga (1993, chap. 9, pp. 159–75) has developed an account in which the relations of probability are grounded in the contingent construction of our cognitive faculties, which in many cases need not involve perceptions of logical relations. In his account, for instance, we think that the future will resemble the past, since those aspects of properly functioning human cognitive faculties that are aimed at truth normally incline us to believe that the future will resemble the past. Similarly, we accept simpler theories over complex ones for the same reason. Because of their stress on the contingent construction of our cognitive faculties, I call views such as Plantinga's *noetic conceptions* of epistemic probability.

The account of epistemic probability that I favor is one in which epistemic probabilities are grounded in some combination of both the contingent construction of our cognitive faculties and the perceived logical relations among propositions. For the purposes of this chapter, I will leave it as an open question which of these conceptions of epistemic probability – the logical, the epistological, the noetic, or some combination thereof – is ultimately correct. A word, however, needs to be said about a problem with Plantinga's account of epistemic probability that is relevant for our purposes. Plantinga defines the conditional epistemic probability of a Proposition A on a Proposition B as follows:

> **Plantinga's Definition of Conditional Epistemic Probability:** P(A|B) = <x,y> iff <x,y> is the smallest interval which contains all the intervals which represent the degree to which a rational human being S (for whom the conditions necessary for warrant hold) could believe A if she believed B, *had no undercutting defeater for A, had no other source of warrant either for A or for -A, was aware that she believed B, and considered the evidential bearing of B on A*. (1993, p. 169; italics added)

Plantinga's account of conditional epistemic probability is a counterfactual account that defines epistemic probability in terms of the degree of warrant a rational human being would have in A if she believed B and had no other sources of warrant for A or –A. The italicized portion, which we shall call Plantinga's *condition of epistemic probability* (CEP), primarily does the job of excluding contributions to our warrant which arise from our epistemic circumstances and other information besides B that is part of our background information k.

We cannot go into a detailed analysis of this account of conditional epistemic probability here. However, we shall consider one major objection that is relevant to the way in which we shall be using epistemic probability. As Bas van Fraassen has pointed out, Plantinga's account does not account for those cases in which B could not be the sole source of warrant for A, an objection that Plantinga attempts to address (1993, p. 168–9). This problem arises in the case of the fine-tuning argument, since we claim that the epistemic probability of LPU is very small under NSU. Our own existence in a body, however, provides a source of warrant for LPU, and it is a source that we cannot eliminate without severely altering our cognitive faculties (or epistemic conditions) in a way that would undermine our rationality.

More recently, Richard Otte has given new teeth to the objection to Plantinga's account raised by van Fraassen. Among other examples, Otte asks us to consider the following variation of one of Plantinga's examples:

P (people are sometimes appeared to redly **|** I am appeared to redly)

According to Otte:

> Intuitively this probability is 1; if I am appeared to redly, it must be the case that people are sometimes appeared to redly. But Plantinga claims that it is not possible for a rational person's sole source of warrant for *people are sometimes appeared to redly* to be *I am appeared to redly*.

> Thus this probability is undefined according to CEP, even though it obviously has a value of 1. This example shows that CEP does not account for our intuitive notion of conditional epistemic probability. (2006, p. 87)

Otte locates the problem with Plantinga's account in his use of counterfactuals, claiming that spelling out conditional epistemic probability in terms of counterfactuals is the wrong approach. Some sort of counterfactual element, however, is essential to any account of conditional epistemic probability if we are to connect degrees of conditional epistemic probability with actual rational degrees of belief, which we need to do if judgments of conditional probability are to serve as guides to life. This requirement, however, does not imply that we must provide a purely counterfactual analysis of conditional epistemic probability; all it demands is that counterfactuals will play some role in connecting conditional epistemic probability with rational degrees of belief.

Although I cannot develop this idea in detail here, I propose that conditional epistemic probability should be conceived as a relation between propositions that is in part determined by the contingent nature of our cognitive faculties. Through introspection, we have partial access to this relation. We typically determine the epistemic probability, $P(A|B)$, of Proposition A on Proposition B – that is, the degree of rational inclination B should give us for A – by artificially creating in our own minds Plantinga's conditions for CEP – that is, by "bracketing out" all other sources of warrant for A or –A, and any undercutting defeaters for A. Thus, for instance, suppose I see it raining outside but want to access the conditional epistemic probability of "it will rain today" (Proposition A) on Proposition B, where B is the conjunction of the claim that "www.weather.com has predicted a 25 percent chance of rain" and other background information, such as that www.weather.com is reliable weather predictor. In assessing this conditional probability, I block out all other sources of warrant for its raining today (such as seeing dark clouds on the horizon), except for Proposition B, and arrive at the correct conditional probability, $P(A|B) = 0.25$. The fact that, for the cases when CEP applies, I come to know these counterfactual degrees of warrant by means of this "bracketing procedure" strongly suggests that epistemic probability should not be identified with counterfactual degrees of belief. *Rather, it should be considered a non-reducible relation of support or warrant existing between propositions that comes in degrees, is partially dependent on our cognitive faculties, and which we can know by introspection via the "bracketing procedure." This relation in turn gives rise to the corresponding counterfactual degrees of warrant when CEP is met.*

The fact that conditional epistemic probability should be considered such a relation existing between propositions that we determine by the "bracketing procedure" is supported by other examples. Consider, for instance, the conditional epistemic probability, $P(A|B \& k')$, of the claim that "human beings exist today" (claim A) based on the claim that the asteroid that supposedly killed the dinosaurs missed planet Earth (claim B) and certain relevant scientific theories (k') regarding the conditions necessary for the evolution of hominids. Given B and k', I might judge it would be very unlikely that the dinosaurs would have become extinct, and hence very unlikely that humans would exist: that is, I would judge $P(A|B \& k') \ll 1$. The procedure I would go through is that of bracketing out all other sources of warrant for A except the relevant scientific theories, k', and claim B, and then access the degree to which ~~all that~~ information warranted or supported A. For instance, I would bracket out all those everyday pieces of information that imply the existence of human beings. Since CEP cannot be met in this case, the existence of a conditional epistemic probability in this case shows that identifying epistemic probability with counterfactual degrees of warrant (or belief or credence) cannot be right.

Part of the purpose of this section is to provide a theoretical underpinning for both the existence of conditional epistemic probability and the claim that P(A|B & k′) can exist for those cases in which the Proposition B & k′ cannot be the sole source of warrant for A. Such a claim is crucial to the likelihood (and probabilistic tension) formulation of the fine-tuning argument, since LPU will be improbable only on background information k′ in which the information that embodied, conscious observers exist is subtracted out of our background information k (see Sections 4.3 and 4.4). Since all rational people believe that they are embodied, it is impossible for k′ & NSU to be the sole source of warrant for LPU. Hence, Plantinga's CEP cannot be met for P(LPU|k′ & NSU). Despite these theoretical underpinnings, some still might question whether there can exist relations of epistemic probability in those cases in which the antecedent (B & k′) cannot be the sole source of warrant for the consequent (A).

To further support the existence of epistemic probabilities in these cases, consider the sorts of cases, such as those mentioned earlier, in which scientific confirmation appears to depend on claims that some state of affairs S – such as the agreement of the various methods of determining Avogadro's number – is expected under a certain hypothesis h, but very epistemically improbable under the negation of that hypothesis, ~h. Suppose we discovered for one of these cases that S was also necessary for our own existence. It seems clear that such a discovery would not itself undermine the confirmation argument in favor of the approximate truth (or empirical adequacy) of the theory. If it did, then we could undermine the support based on the Likelihood Principle for many theories of physics simply by discovering that the state of affairs S predicted by the theory – for example, the degree of bending of light around the Sun predicted by General Relativity – was necessary for embodied conscious life. This seems clearly wrong. Thus, there must be a probability for P(S|~h & k′) in these cases, where k′ is some appropriately chosen background information that does not implicitly or explicitly include the fact that humans exist. (If k′ included that humans exist, then P(S|~h & k′) = 1, destroying any likelihood confirmation; see Section 4.3 for more discussion on choosing k′ in cases like this.)

As a specific example, consider QED's precise prediction of the deviation from 2 of the gyromagnetic moment of the electron to nine significant digits, as discussed in Section 3.3.3. In terms of the Likelihood Principle, the reason this prediction has been thought to significantly confirm QED is that such a precise, correct prediction seems very epistemically unlikely if QED is *not* approximately true (or at least empirically adequate), but it is epistemically likely if QED is true.[21] Suppose we discovered that this precise magnitude of deviation was necessary for the evolution of life in our universe. It seems clear that this would not undermine the confirmation that this precise prediction gives to QED.

Finally, since no rational person could doubt LPU, it will often be useful to use the following conceptual device to intuitively grasp the relations of conditional epistemic probability for LPU conditioned on NSU & k′ and conditioned on T & k′. The device is to

21. The importance of this example, and others like it, is that insofar as the confirmation in question admits a likelihood reconstruction, it clearly involves epistemic probabilities that cannot be reduced to statistical or theoretical probabilities (since the predicted value has to do with the basic structure of our universe), and it is one in which we can plausibly conceive of it as having some anthropic significance.

imagine an unembodied alien observer with cognitive faculties structurally similar to our own in the relevant ways, and then ask the degrees of credence that such a being would have in LPU given that he or she believes in NSU & k′ or in T & k′. This device of the unembodied alien observer should remove any lingering doubts about the existence of a conditional epistemic probability on background information k′ that we could not have – for example, when k′ does not implicitly or explicitly include the existence of embodied conscious beings. Given that such an alien is possible, it could have k′ as its background information and thus would not have the aforementioned problem regarding the existence of an epistemic probability for LPU on k′; hence, the existence of LPU could significantly confirm T over NSU for that being. It seems clear that if we met such a being and if we discovered that LPU confirmed T over NSU for that being, then it should do so for us too.[22]

I believe the various arguments I have offered establish both the crucial role of epistemic probabilities in scientific confirmation and their existence between some Propositions A and B & k′ in those cases in which B & k′ could never be the sole source of warrant (or justification) for A. Our next question is how to determine P(A|B & k′).

3.3. Determining epistemic probability

3.3.1. Introduction

Now that we know what we mean by epistemic probability, it is time to consider how it is justified. In science, many times epistemic probability is determined by an appeal to intuition, such as many of the epistemic probabilities considered in the last section – for example, those arising in conjunction with the Thesis of Common Ancestry, continental drift theory, and atomic theory. These probabilities clearly were not justified by an appeal to statistical improbability – for example, we have no statistics regarding the relative frequency of life on a planet having those features cited in favor of evolution either under the evolutionary hypothesis or under some nonevolutionary hypothesis. Indeed, these judgments of epistemic probability were never rigorously justified in any way. Rather, after (we hope) doing their best job of looking at the evidence, scientists and laypersons made judgments of what kind of world we should expect under each hypothesis, and then they simply trusted these judgments. This sort of trust in our judgments of epistemic probability is a pervasive and indispensable feature of our intellectual life. It is these sorts of intuitive judgments, I contend, that ultimately ground the claim that, given the evidence for the first type of fine-tuning we discussed in Section 2.2 – that of the laws of nature – it is very epistemically unlikely that such a universe would exist under NSU & k′.

Of course, the more widely shared these judgments are by those who are relevantly informed, the more seriously we take them. In this regard, it should be noted that, given the fine-tuning data, the judgment that LPU is surprising under naturalism is widely shared by intelligent, informed individuals, as evidenced by the various attempts to account for

22. For a denial of the kind of claim that I make here – namely, that the confirmation must be the same for the unembodied being and us – see Sober (2005, pp. 137–40). For a critique of Sober, see footnote in Section 7.5. Even if Sober is correct, my other arguments still hold for thinking there could exist an epistemic probability of LPU on k′ & NSU and k′ & T. Further, these arguments show that confirmation can still occur even when there is an observer selection effect, such as the aforementioned thought experiments in which we discovered that the data in support of atomic theory or QED had anthropic significance.

it, such as the multiverse hypothesis. Of course, the skeptic might object that scientific theories are testable, whereas the theistic explanation is not. But why should testability matter with regard to the acceptability of our judgments of epistemic probability? After all, testability is about being able to find evidence for or against a theory in the future, not about the present likelihood of the theory or the likelihood of some body of data's being the case if the theory is false or not empirically adequate. Thus, I contend, the merely intuitive judgments of epistemic probability in the case of fine-tuning are on as solid ground as many of those accepted in science that cannot be rigorously justified. It is dishonest, therefore, to accept one sort of inference without rigorous justification but reject the other merely because it purportedly lacks such justification. At any rate, we shall present such justification for judgments of epistemic probability in the case of the fine-tuning of the constants of physics, regarding which I shall argue that we can go beyond a mere appeal to intuition. Instead, we can provide a solid, principled justification based on what I shall call the restricted Principle of Indifference, which we shall discuss in the next two subsections.[23]

3.3.2. Restricted Principle of Indifference

According to the *restricted Principle of Indifference*, when we have no reason to prefer any one value of a variable p over another in some range R, we should assign equal epistemic probabilities to equal ranges of p that are in R, given that p constitutes a "natural variable." A variable is defined as "natural" if it occurs within the simplest formulation of the relevant area of physics. When there is a range of viable natural variables, then one can only legitimately speak of the range of possible probabilities, with the range being determined by probabilities spanned by the lower and upper bound of the probabilities determined by the various choices of natural variables.

Since the constants of physics used in the fine-tuning argument typically occur within the simplest formulation of the relevant physics, the constants themselves are natural variables. Thus, the restricted Principle of Indifference entails that we should assign epistemic probability in proportion to the width of the range of the constant we are considering. We shall use this fact in Section 5.1 to derive the claim that $P(Lpc|NSU \& k') \ll 1$, where Lpc is the claim that the value for some fine-tuned constant C falls within the life-permitting range.

To see why the restriction to a natural variable is needed, consider the case in which we are told that a factory produces cubes between 0 and 10 meters in length, but in which we are given no information about what lengths it produces. Using our aforementioned principle, we shall now calculate the epistemic probability of the cube being between 9 and 10 meters in length. Such a cube could be characterized either by its length, L, or its volume, V. If we characterize it by its length, then since the range [9,10] is one-tenth of the possible range of lengths of the cube, the probability would be 1/10. If, however, we characterize it by its volume, the ratio of the range of volumes is: $[1{,}000 - 9^3]/1{,}000 = [1{,}000 - 729]/1{,}000 = 0.271$, which yields almost three times the probability as for the case of using

23. A rigorous justification of the epistemic improbability of the initial conditions of the universe is a little trickier, since it presupposes that one can apply the standard measure of statistical mechanics to the initial state of the universe, something John Earman and others have questioned (see Section 2.4). We cannot pursue this issue further in this chapter, however.

length. Thus, the probability we obtain depends on what mathematically equivalent variable we use to characterize the situation.

In the case of the constants of physics, one can always find some mathematically equivalent way of writing the laws of physics in which W_r/W_R is any arbitrarily selected value between zero and one. For example, one could write Newton's law of gravity as $F = U^{100}m_1m_2/r^2$, where U is the corresponding gravitational constant such that $U^{100} = G$. If the comparison range for the standard gravitational constant G were from 0 to $10^{100}G_0$, and the life-permitting range were from 0 to 10^9 G_0, that would translate to a comparison range for U of 0 to $10U_0$ and a life-permitting range of 0 to $1.2U_0$, since $10U_0 = 10^{100}G_0$ and $1.2U_0 = 10^9G_0$. (Here G_0 is the present value of G and U_0 would be the corresponding present value of U.) Thus, using G as the gravitational constant, the ratio, W_r/W_R, would be $10^9G_0/10^{100}G_0 = 1/10^{91}$, and using U as the "gravitational constant," it would be $1.2U_0/10U_0$, or 0.12, a dramatic difference! Of course, $F = U^{100}m_1m_2/r^2$ is not nearly as simple as $F = Gm_1m_2/r^2$, and thus the restricted Principle of Indifference would only apply when using G as one's variable, not U.

Examples such as that of the cube mentioned have come to be known as the Bertrand Paradoxes (see e.g. Weatherford 1982, p. 56). Historically, this has been thought of as the fatal blow to the general applicability of the Principle of Indifference, except in those cases in which a natural variable can be determined by, for instance, symmetry considerations such as in statistical mechanics. In the next section, however, we shall see that for purposes of theory confirmation, scientists often take those variables that occur in the simplest formulation of a theory as the natural variables. Thus, when there is a simplest formulation, or nontrivial class of such formulations, of the laws of physics, the restricted Principle of Indifference circumvents the Bertrand Paradoxes.

Several powerful general reasons can be offered in defense of the Principle of Indifference if it is restricted in the ways explained earlier. First, it has an extraordinarily wide range of applicability. As Roy Weatherford notes in his book, *Philosophical Foundations of Probability Theory*, "an astonishing number of extremely complex problems in probability theory have been solved, and usefully so, by calculations based entirely on the assumption of equiprobable alternatives [that is, the Principle of Indifference]" (1982, p. 35). Second, in certain everyday cases, the Principle of Indifference seems the only justification we have for assigning probability. To illustrate, suppose that in the last 10 minutes a factory produced the first 20-sided die ever produced (which would be a regular **icosahedron).** Further suppose that every side of the die is (macroscopically) perfectly symmetrical with every other side, except for each side having different numbers printed on it. (The die we are imagining is like a fair six-sided die except that it has 20 sides instead of six.) Now, we all immediately know that upon being rolled the probability of the die coming up on any given side is one in 20. Yet we do not know this directly from experience with 20-sided dice, since by hypothesis no one has yet rolled such dice to determine the relative frequency with which they come up on each side. Rather, it seems our only justification for assigning this probability is the Principle of Indifference: that is, given that every side of the die is macroscopically symmetrical with every other side, we have no reason to believe that it will land on one side versus any other. Accordingly, we assign all outcomes an equal probability of one in 20.[24]

24. A full-scale defense of the restricted Principle of Indifference is beyond the scope of this chapter. See Schlesinger (1985, chap. 5) for a lengthy defense of the standard Principle of Indifference.

In the next section, I shall first offer a powerful reason for epistemically privileging those variables that occur in the simplest overall formulation of the relevant domain of physics. I shall then show how this reason offers a further, strong support for the restricted Principle of Indifference based on scientific practice.

3.3.3. Natural variable assumption

Typically, in scientific practice, precise and correct novel predictions are taken to significantly confirm a theory, with the degree of confirmation increasing with the precision of the prediction. We shall argue, however, that the notion of the "precision" of a prediction makes sense only if one privileges certain variables – the ones that I shall call the *natural variables*. These are the variables that occur in the simplest overall expression of the laws of physics. Thus, epistemically privileging the natural variables as required by the restricted Principle of Indifference corresponds to the epistemic practice in certain areas of scientific confirmation; if scientists did not privilege certain variables, they could not claim that highly precise predictions confirm a theory significantly more than imprecise predictions.

We begin our argument by considering only cases in which the predictions of a theory are accurate to within experimental error. In such cases, the known predictive precision will be equal to the *experimental precision* of the measured quantity. Our fundamental premise will then be that everything else being equal, the confirmation that a prediction offers a theory increases with the *known precision* of a prediction.

The experimental precision of a measurement of a quantity is dependent on the experimental error. In standard scientific notation, the experimental value of a quantity is often expressed as $V \pm e$, where e indicates that one's measuring apparatus cannot distinguish between values that differ by more than e. More precisely, to say that the experimentally determined value is $V \pm e$ indicates that we have a certain set degree of confidence – usually chosen to be 95 percent – that the actual value is within the interval $[V + e, V - e]$. So, for example, one might measure the weight of a person as 145.3 lb ± 0.1: that is, the experiment gives us a 95 percent confidence that the person's weight is within the interval [145.4 lb, 145.2 lb].

Scientists often speak of experimental accuracy/precision in terms of significant digits. Thus, in the above example, the precision is three significant digits since one's measuring apparatus cannot determine whether the person weighs 145.4 lb or 145.2 lb, and thus only three digits (i.e. 145) can be relied on to give one the value of the weight. Because sometimes zeroes can be "placeholder" digits that determine the order of magnitude of a quantity, these digits are not considered significant. For example, the zeroes in 0.000841 are placeholder digits. To eliminate counting placeholder digits as significant, one can simply express the measured value in terms of scientific notation, and then count the number of digits that are within the margin of error. Thus, a measurement of 0.000841 ± 0.000002 meters for the length of a piece of steel expressed in scientific notation becomes $8.41 \pm 0.02 \times 10^{-4}$ meters, which yields an accuracy of two significant digits. This measure of precision will not work for those cases in which the measured value is zero, nor should it even be applied to those cases in which the measured value is less than the error.

A more precise way of thinking about this kind of precision is in terms of the ratio of the width, W_r, of the confidence interval $[V + e, V - e]$ to the value of V, with the restriction that $V > e$. Under this notion of precision, to say that the experimental value has a precision of δ means that Abs[W_r/V] < δ, where Abs denotes the absolute value of the quantity in brackets, and W_r denotes the width of the range [V + e, V – e] – that is, 2e. There is a rough correspondence between precision expressed in terms of this ratio and in terms of significant digits: a precision of n significant digits roughly corresponds to a ratio of one in 10^n. Thus, in our weight example, $W_r = 2e = 0.2$, and hence $W_r/V = 0.2/145 \sim 1/1{,}000$.

A more careful analysis would reveal that scientists only consider significant digit (SD) precision as a guide to what I call W_R precision, which is the ratio of the width, W_r, of the experimentally determined/predicted range for a variable to what is estimated to be the width of the expected range, W_R, for the variable given the background information. The actual value, V, is then taken as a guide to the width of the theoretically possible range, and hence $W_r/W_R \sim$ Abs[e/V], where ~ means approximately. We shall return to this issue when we discuss QED, but for the purposes of this chapter, we are concerned only with showing that determining the degree of precision of a prediction – whether SD or W_R precision – depends on privileging the natural variable(s) as defined.

Finally, one might wonder why we cannot define precision simply as the amount that, with a set degree of probability, the actual value could differ from the experimental value. We could, but it would be a useless notion when it came to the question of experimental confirmation. For example, how could we compare the confirmatory value of a predictive precision of 1 kg with that of 1 μm? Or, is it really plausible to say that, for instance, a predictive precision of 20 significant digits of the mass of the universe has less confirmatory significance than a prediction of one significant digit of the mass of a hydrogen atom because the former is less accurate in terms of number of kilograms by which the actual value could differ from the predicted value?

We shall now argue that if either the degree of SD precision or the degree of W_R precision is epistemically relevant, it follows that one must privilege variables that are closely tied with the natural variables. We shall start by showing that SD experimental precision depends on the variable one uses to represent the quantity being measured; consequently, in order to speak of precision in a nonrelative sense, one must specify the variable one is using to express the physical situation. To illustrate, consider the case of a cube discussed in the last section. The volume of a cube is equal to the third power of the length of its side: $V = L^3$. Suppose we determine the length of the cube is 10 μm, to within a precision of 1 μm. Thus, expressed as a ratio, the SD precision is Abs[e/V] < 1/10, or one part in 10. Roughly, this means that the length of the cube could be anywhere from 9 to 11 μm. In terms of volume, however, the cube can vary between $9^3 = 729\ \mu m^3$ and $11^3 = 1{,}331\ \mu m^3$. This means that the experimental precision is (1,331–1,000)/1,000 ~ 1/3, or one part in three, if we take volume as our variable.

Now consider a theory that predicts that the length of the side of the cube is 10 μm. This is equivalent to the theory predicting the volume of the cube to be 1,000 μm. In this case, the predicted value agrees with the experimental value to within experimental precision. If we ask what the known precision of the prediction is, however, we do not get a definite answer. If we consider the theory as predicting the length of the cube, we get one value for the known precision, whereas if we consider the theory as predicting the volume, we get another value for the precision. (Remember, since we are assuming that the theory predicts the correct value to within experimental error, the known predictive precision is equal to the experimental precision.) The moral here is that the known precision of a prediction depends on the mathematical variable – for example, L^3 or L in the said example – under which one is considering the prediction. Put differently, *one can speak of precision of* *an experimentally correct prediction only relative to the variable one uses to represent the predicted result*. In analogy to Bertrand's Cube Paradox for the Principle of Indifference, in the case of the aforementioned cube it seems that we have no *a priori* way of choosing between expressing the precision in terms of volume or in terms of length, since both seem equally natural. At best, all we can say is that the predicted precision is somewhere between that determined by using length to represent the experimental data and that determined by using volume to represent the experimental data.

For an illustration from actual physics, consider the case of QED's astoundingly accurate prediction of the correction of the gyromagnetic ratio – called the *g*-factor – of the electron due to its self-interaction. QED predicted that, because of the self-interaction of the electron, the *g*-factor (gyromagnetic moment) of the electron differs from 2 by a small amount: $g/2 = 1.001\,159\,652\,38 \pm 0.000\,000\,000\,26$. Very accurate experimental measurements yielded: $g/2 = 1.001\,159\,652 \pm 0.000\,000\,000\,20$. The precision of the said prediction of $g/2$ is one part in a billion.

Now determining the experimental value for $g/2$ is equivalent to determining the experimental value of some arbitrarily defined function $U(g/2)$ of $g/2$, say $U(g/2) = (g/2)^{100}$. Moreover, if QED predicted the value of $g/2$ to within experimental error, then it follows that it also predicted the correct value of U to within experimental error. The precision by which U is known, however, is one in 10 million instead of one in a billion, as in the case of $g/2$. Thus, in analogy to the case of probability, even to speak of the precision of QED's prediction, we must already assume a certain natural variable. It seems that the only nonarbitrary choices are the natural variables defined earlier, which is what scientists actually use.

From examples like the one cited earlier, it is also clear that W_R precision also depends on the choice of the natural variable, as we explained for the case of fine-tuning. So it seems that in order to speak of the predictive SD or W_R precision for those cases in which a theory predicts the correct experimental value for some quantity, one must assume a natural variable for determining the known predictive precision. One could, of course, deny that there exists any nonrelative predictive precision, and instead claim that all we can say is that a prediction has a certain precision relative to the variable we use to express the prediction. Such a claim, however, would amount to a denial that highly accurate predictions, such as those of QED, have any special epistemic merit over predictions of much less precision. This, however, is contrary to the practice of most scientists. In the case of QED, for instance, scientists did take the astounding, known precision of QED's prediction of the *g*-factor of the electron, along with its astoundingly accurate predictions of other quantities, such as the Lamb shift, as strong evidence in favor of the theory. Further, denying the special merit of very accurate predictions seems highly implausible in and of itself. Such a denial would amount to saying, for example, that the fact that a theory correctly predicts a quantity to an SD precision of, say, 20 significant digits does not, in general, count significantly more in favor of the theory than if it had correctly predicted another quantity with a precision of two significant digits. This seems highly implausible.

Of course, strictly speaking, to make these sorts of comparisons of relative degrees of confirmation, one need not privilege one particular variable for expressing the experimental result and calculating its precision, since one need not be committed to a specific degree of precision. Nonetheless, one must put some significant restrictions on the functions of a given variable on which one bases one's calculation of precision, for otherwise one cannot make any significant comparisons. For example, in some cases, there might be several different equally simple ways of writing the laws of physics, giving rise to several different candidates for natural variables. In that case, one would simply say that the degree of precision fell into a certain range covering the different choices of natural variables.

Finally, consider a Likelihood Principle reconstruction of the confirmation that QED received from its correct, precise prediction of the correction to the *g*-factor of the electron. Let QED represent the claim that QED is approximately true or at least empirically adequate; let ~QED represent the negation of this claim; finally, let e represent the fact that the correction to the *g*-factor of the electron falls within the experimentally determined range. Now, P(e|QED & k′) = 1, since QED entails that it will fall into the experimentally determined range. (Since e was old evidence at the time of QED's prediction, k′ is our background minus this old evidence). The value of P(e|~QED & k′) will depend on the comparison range one chooses – that is, the range of plausible values for the correction to the *g*-factor given ~QED & k′. There is no precise way of determining this range, but given that without any correction, the *g*-factor is 2, it is reasonable to suppose that most physicists would have expected it to be no larger than 2. Suppose that it were reasonable to expect the correction to be no greater than ± 0.01, with no preference for any value between 0 and ± 0.01. This would yield a width, W_R, for the comparison range of 0.02. If we let W_r be the range of the experimentally determined value of correction, and we used the restricted Principle of Indifference, we would arrive at P(e|~QED & k′) = $W_r/W_R \sim 10^{-7}$, yielding a large likelihood confirmation of QED over ~QED.

The lesson here is that any support that correct, precise predictions provide for QED over ~QED via the Likelihood Principle will involve using something similar to the restricted Principle of Indifference, with the epistemically privileged natural variables being those in the simplest formulation of the area of physics in question. The same can be said for the likelihood reconstruction of other cases of confirmation based on precise predictions. Such likelihood reconstructions, if plausible, strongly support the epistemic role of the restricted version of the Principle of Indifference in scientific practice.

4. Determining k′ and the Comparison Range

4.1. Introduction

To complete the philosophical groundwork for our argument, we shall need to provide some way of determining k′. Determining k′ will automatically determine the "possible universes" to which we are comparing the life-permitting ones – that is, what we called the "comparison range." We shall focus on the constants of physics, but everything we say applies to the laws and initial conditions of the universe with minor modifications. First, however, we need to get clear on what it means to vary a constant of physics.

4.2. What it means to vary a constant of physics

Intuitively, there is a distinction between laws and constants, and physicists usually suppose such a distinction. In current physics, most laws can be thought of as mathematical descriptions of the relations between certain physical quantities. Each of these descriptions has a mathematical form, along with a set of numbers that are determined by experiment. So, for example, Newton's law of gravity ($F = Gm_1m_2/r^2$) has a mathematical form, along with a number (G) determined by experiment. We can then think of a world in which the relation of force to mass and distance has the same mathematical form (the form of being proportional to the product of the masses divided by the distance between them squared), but in which G is different. We could then say that such worlds have the same law of gravity, but a different value for G. So when we conceive of worlds in which a constant of physics is different but in which the laws are the same, we are conceiving of worlds in which the mathematical form of the laws remains the same, but in which the experimentally determined numbers are different. It should be noted that the distinction between laws and constants need not be a metaphysical distinction, but only a conceptual distinction.

Now these constants of physics are relative to our current physical models, since these constants only occur within a model. Thus, any probabilities we calculate will only be relative to a certain model. Ian Hacking (1987, pp. 119–227) and Bas van Fraassen (1980, pp. 178–95), among others, have emphasized this model-relativism with regard to the relative frequency interpretation of probabilities. Under this interpretation, probabilities are understood as the limit of the ratio of the favorable outcomes to the total number of outcomes as the number of trials goes to infinity. Since for most, if not all, cases these infinite long-run frequencies do not exist in the real world, they ultimately must make reference to frequencies in idealized models, as van Fraassen has worked out in detail (1980, pp. 190–3). Similarly, I shall assume, epistemic probabilities exist only relative to our models of the world and our other background information.

At least in the case of epistemic probabilities, this should come as no surprise, since it has to do with rational degrees of belief, which, of course, are relative to human cognition. If one denies the model dependence of epistemic probabilities, then it is hard to see how any statements of epistemic probabilities will ever be justified. One reason is that they are almost always grounded in conceptualizing alternative possibilities under some measure, as illustrated in Section 3.1 by the sort of epistemic probabilities used to justify the Thesis of Common Ancestry, continental drift theory, or the atomic hypothesis. But such conceptualizations typically involve implicit reference to some (often vague) model of how those possibilities are spread out. In fact, this was illustrated by use of natural variables in science discussed in Section 3.3.3.

The relevant models for the fine-tuning hypothesis are just the models given to us by our best theories in physics, just as if we calculated relative frequencies we should do so using the best models that we had in the relevant domain. At present, the best model we have is the Standard Model of particle physics. Sometimes, however, we can calculate the life-permitting range only for a constant that is less than fundamental, either because we do not have a fundamental theory or because of limitations on our ability to calculate. In that case, the most sensible thing to do is to go with the best model for which we can do calculations, as long as we consider only variations in the constant that fall within the limits of applicability of the model established by the deeper theory –for example, we could sensibly consider the consequences of varying mass using the model of Newton's theory of gravity as long as the variation were within the range of validity of Newtonian mechanics dictated by Einstein's theory of General Relativity.

Because we are considering only one reference class of possible law structures (that given by variations of the constants within our best theories and/or the ones we can perform calculations for), it is unclear how much weight to attach to the values of epistemic probabilities one obtains using this reference class. Hence, one cannot simply map the epistemic probabilities obtained in this way onto the degrees of belief we should have at the end of the day. What we can do, however, is say that given that we choose our reference class in the way suggested, and assuming our other principles (such as the restricted Principle of Indifference in Section 3.3.2), we obtain a certain epistemic probability, or range of probabilities. Then, as a second-order concern, we must assess the confidence we have in this probability based on the various components that went into the calculation, such as the representative nature of the reference class. Given that there is no completely objective procedure for addressing this secondary concern, I suggest that the probability calculations should be thought of as ~~simply~~ providing supporting confirmation, based on a plausible, nonarbitrary procedure, of the common intuitive sense that given the fine-tuning evidence, LPU is very epistemically improbable under NSU. This evidence will be strengthened by the fact that there are many different fine-tuned constants of physics, and many different kinds of fine-tuning, so that the fine-tuning argument does not depend on one highly specific reference class. In light of this, we must keep in mind that our goal is to provide some exact degree by which the fine-tuning evidence supports T over NSU. Rather, it is to show that the intuitive sense that LPU supports T over NSU is not based on some mistake in thinking or perception, or on some merely subjective interpretation of the data, but rather can be grounded in a justified, nonarbitrary procedure.[25]

4.3. Determining k': old evidence problem

In Premises (1) and (2) of our main argument in Section 1.3, the probability of LPU is conditioned on background information k'. As we mentioned in Section 1.3, we cannot simply take k' to be our entire background information k, since k includes the fact that we exist, and hence entails LPU. To determine what to include in k', therefore, we must confront what is called the "problem of old evidence." The much-discussed problem is that if we include known evidence e in our background information k, then even if an hypothesis h entails e, it cannot confirm h under the Likelihood Principle, or any Bayesian or quasi-Bayesian methodology, since $P(e|k \,\&\, h) = P(e|k \,\&\, \sim h)$. But this seems incorrect: General Relativity's prediction of the correct degree of the precession of the perihelion of Mercury (which was a major anomaly under Newton's theory of gravity) has been taken to confirm General Relativity even though it was known for over 50 years prior to the development of General Relativity and thus entailed by k.

An attractive solution to this problem is to subtract our knowledge of old evidence e from the background information k and then relativize confirmation to this new body of information $k' = k - \{e\}$. As Colin Howson explains, "when you ask yourself how much support e gives [hypothesis] h, you are plausibly asking how much knowledge of e *would* increase the credibility of h," but this is "the same thing as asking how much e boosts h relative to what else we know" (1991, p. 548). This "what else" is just our background knowledge k minus e. As appealing as this method seems, it faces a major problem: there

25. Given the multiplicity of possible references classes, one could simply decide not to assign any epistemic probability to LPU. As with skepticism in general, such a practice would also undercut any sort of rational commitment to the approximate truth or empirical adequacy of a theory, since the epistemic probabilities used in justifying these theories also lack a complete fundamental justification. Given that we are not skeptics, the best we can do is use the least arbitrary procedure available to assign epistemic probabilities.

is no unambiguous way of subtracting e from k. Consider the case of the fine-tuning of the strength of gravity. The fact, Lpg, that the strength of gravity falls into the life-permitting range entails the existence of stable, long-lived stars. On the other hand, given our knowledge of the laws of physics, the initial conditions of the universe, and the value of the other constants, the existence of stable, long-lived stars entails Lpg. Thus, if we were to obtain k′ by subtracting Lpg from our total background information k without also subtracting our knowledge of the existence of long-lived stable stars from k, then P(Lpg|k′) = 1.

To solve such problems, Howson says that we should regard k as "in effect, an independent axiomatization of background information and k – {e} as the simple set-theoretic subtraction of e from k″ (1991, p. 549). That is, Howson proposes that we axiomatize our background information k by a set of sentences {A} in such a way that e is logically independent of the other sentences in {A}. Then k′ would simply consist of the set of sentences {A} – e. One serious problem with this method is that there are different ways of axiomatizing our background information. Thus, as Howson recognizes, the degree to which e confirms h becomes relative to our axiomatization scheme (1991, p. 550). Howson argues that in practice this is not as serious a problem as one might expect, since in many cases our background information k is already represented to us in a partially axiomatized way in which e is logically isolated from other components of k. As he notes, "the sorts of cases which are brought up in the literature tend to be those in which the evidence, like the statements describing the magnitude of the observed annual advance of Mercury's perihelion, is a logically isolated component of the background information." (1991, p. 549). In such cases, when we ask ourselves how much e boosts the credibility of h with respect to what else we know, this "what else we know" is well defined by how we represent our background knowledge. Of course, in those cases in which there are alternative ways of axiomatizing k that are consistent with the way our background knowledge is represented to us, there will be corresponding ambiguities in the degree to which e confirms h. I agree with Howson that this is not necessarily a problem unless one thinks that the degree of confirmation e provides h must be independent of the way we represent our background knowledge. Like Howson, I see no reason to make this assumption: confirmation is an epistemic notion and thus is relative to our epistemic situation, which will include the way we represent our background information.

In the case of fine-tuning, our knowledge of the universe is already presented to us in a partially axiomatized way. Assuming a deterministic universe, the laws and constants of physics, along with the initial conditions of the universe, supposedly determine everything else about the universe. Thus, the set of propositions expressing these laws, constants, and initial conditions constitutes an axiomatization of our knowledge. Further, in scientific contexts, this represents the *natural* axiomatization. Indeed, I would argue, the fact that this is the natural axiomatization of our knowledge is part of our background knowledge, at least for scientific realists who want scientific theories to "cut reality at its seams."[26] Furthermore, we have a particularly powerful reason for adopting this axiomatization when considering a constant of physics. The very meaning of a constant of physics is only defined

26. One might object that this procedure is only justified under the assumption that we live in a deterministic universe, since, otherwise, the k we have chosen is not a true axiomatization of our knowledge. This is true, but it is difficult to see how the thesis that the world is indeterministic could be relevant to the legitimacy of the fine-tuning argument.

in terms of a particular framework of physics. Saying that the strong force constant has a certain value, for instance, would be meaningless in Aristotelian physics. Accordingly, the very idea of subtracting out the value of such a constant only has meaning relative to our knowledge of the current set of laws and constants, and hence this constitutes the appropriate axiomatization of our relevant background information k with respect to which we should perform our subtraction.

Using Howson's method, therefore, we have a straightforward way of determining k – {e} for the case of the constants of physics: we let k be axiomatized by the set of propositions expressing the initial conditions of the universe and the laws and fundamental constants of physics within our currently most fundamental theory which we can do calculations. *Since the constants of physics can be considered as given by a list of numbers in a table, we simply subtract the proposition expressing the value of C from that table to obtain k′. Thus, k′ can be thought of as including the initial conditions of the universe, the laws of physics, and the values of all the other constants except C.*

It should be noted that although Howson's method was developed in the context of subjective Bayesian conception of probability, his argument for this method does not depend on this conception. All it depends on is the claim that "when you ask yourself how much support e gives [hypothesis] h, you are plausibly asking how much knowledge of e *would* increase the credibility of h," and that this is "the same thing as asking how much e boosts h relative to what else we know" (1991, p. 548). Anyone who subscribes to a probabilistic confirmation account of evidence, according to which e counts as evidence for h if and only if knowledge of e increases our degree of confidence in h, should at least be sympathetic to the underlying premises of his argument.

Finally, it is worth considering how the old evidence problem plays out in the method of probabilistic tension. As mentioned earlier, the major problem with Howson's method is that the background information k′ depends on the subtraction procedure one uses. If we cast the fine-tuning argument in terms of probabilistic tension, as elaborated in Section 1.4, this problem can be avoided; we do not need to privilege any particular subtraction procedure. According to that method, both NSU and T should be elaborated in such a way that each of them entails LPU. (We called these elaborated hypotheses NSUe and Te, respectively.) Thus, LPU does not directly confirm one of these elaborated hypotheses over the other. Nonetheless, the fine-tuning evidence creates severe probabilistic tension for NSUe but not for Te. Thus, it gives us a significant reason to prefer Te over NSUe: if with respect to some domain, one hypothesis h_1 has much more probabilistic tension than another, h_2, then the probabilistic tension gives us strong reason to prefer h_1 over h_2, everything else being equal.

To determine the degree of probabilistic tension generated for NSUe by the fine-tuning evidence, we need to probe NSUe & k for hidden probabilistic tension related to the fine-tuning evidence. Now, when considering only a single constant C, the fine-tuning evidence only generates probabilistic tension because of the data Lpc. To bring this probabilistic tension out, we first note that NSUe & k = NSU & k = NSU & k′ & Lpc, since k′ = k – {Lpc} and hence k = Lpc & k′, *where no particular subtraction procedure is specified for* –{Lpc}. Then, we must consider all k′ such that k = k′ & Lpc, and take the true probabilistic tension of NSUe & k to be given by the lower bound of P(Lpc|NSU & k′), for all possible k′. We then follow a similar procedure for the probabilistic tension of Te & k. Using the lower bound guarantees that the information that a constant fell into the life-permitting range is not implicitly left in the k′ one uses to assess probabilistic tension, as we saw in our given example for the fine-tuning of gravity where the existence of long lived, stable stars was left in k′. This is a determinate procedure that does not depend on any choice of subtraction procedure and demonstrates the power of the idea of probabilistic tension. (As an alternative to Howson's method, one might also use this approach to determine k′ for the Likelihood Principle method mentioned, although we will not pursue this further here.)

4.4. Determining k′: the EI region

Next, for any given fine-tuned constant C, we must determine the comparison range of values for C. My proposal is that the primary comparison range is the set of values for which we can make determinations of whether the values are life-permitting or not. I will call this range the *epistemically illuminated* (EI) range.[27] Thus, given that the EI range is taken as our comparison range, we will say that a constant C is fine-tuned if the width, W_r, of the range of life-permitting values for the constant is very small compared with the width, W_R, of the EI range.

To motivate the claim that the comparison range, W_R, should be taken as the EI range, we shall consider a more mundane case of a very large dartboard with only some small, finite region around the bull's eye that is illuminated, with the bulk of the dartboard in darkness. In this case, we know neither how far the dartboard extends nor whether there are other bull's eyes on it. If we saw a dart hit the bull's eye in the ~~IL~~ region, and the bull's eye was very, very small compared with the ~~illuminated (IL)~~ region, we would take that as evidence that the dart was aimed, even though we cannot say anything about the density of bull's eyes on other regions of the board.

One way of providing a likelihood reconstruction of the confirmation of the aiming hypothesis is to include the fact that the dart fell into the IL region as part of the information being conditioned on: that is, include it in the background information k′. We could then use the Likelihood Principle to argue as follows: given that we know that the dart has fallen into the IL region, it is very unlikely for it to have hit the bull's eye by chance but not unlikely if it was aimed; hence, its falling in the bull's eye confirms the aiming hypothesis over the chance hypothesis. Similarly, for the case of fine-tuning, we should include the fact that the value of a constant is within the EI region as part of our background information k′.

Is including in k′ the fact that C falls into the EI range an adequate procedure? The case of the dartboard, I believe, shows that it is not only a natural procedure to adopt, but also arguably the only way of providing a Likelihood Principle reconstruction of the inference in this sort of mundane case. First, it is clearly the ratio of the area taken up by the bull's eye to the IL region around the bull's eye that leads us to conclude that it was aimed. Second, one *must* restrict the comparison range to the IL range (i.e. include IL in k′) since one does not know how many bull's eyes are in the unilluminated portion of the dartboard. Thus, if one expanded the comparison range outside the IL range, one could make no estimate as to the ratio of the area of the bull's eye regions to the non-bull's eye regions, and thus could not provide a likelihood reconstruction. Yet it seems intuitively clear that

27. This is a different approach than in one of my earlier papers on the issue (Collins 2005b), where the range was constrained by what values are consistent with a universe's existing – for example, too high of a value for the gravitational constant would reduce the whole universe to a singularity and so forms a natural bound of the range. The "universe existing constraint" is still valid (since NSU & k′ presuppose the existence of a universe), but it is typically trumped by the EI region constraint, since the latter is more stringent.

the dart's hitting the bull's eye in this case does confirm the aimed hypothesis over the chance hypothesis.

Another way of seeing why the comparison range should be equal to the EI range is in terms of the rational degrees of credence in Lpc of the fictional unembodied alien observer introduced at the end of Section 3.2. In accordance with the method of dealing with old evidence, we imagine our alien observer holding background information k′, in which the knowledge of the value of C is subtracted out. Then we imagine that our alien observer learns that C falls into the EI range. Call this new information Q. Even assuming that it makes sense to speak of C as possibly having any value between minus infinity and infinity, the alien observer would not know whether the sum of the widths of all the life-permitting regions outside of the EI region are finite or infinite. Hence, it would not know the value of P(Q|T & k′), since to say anything about the chance of God's creating C in the EI region, it would have to know if there are other life-permitting regions besides the ones in EI. Hence, P(Q|NSU & k′)/P(Q|T & k′) would be indeterminate. This means that knowledge of Q neither confirms nor disconfirms T relative to NSU.

Suppose our alien observer learns the additional information, Lpc, that C falls into the life-permitting region of EI. Since our observer knows Q, assessing whether this additional information confirms T with respect to NSU will depend on the ratio P(Lpc|k′ & Q & T)/P(Lpc|k′ & Q & NSU). Now, since k′ & Q & NSU implies nothing about where C falls in the EI region, it would leave our alien observer indifferent as to where it fell in this region. Hence, assuming the validity of the restricted Principle of Indifference (see Section 3.3.2), P(Lpc|k′ & Q & NSU) = W_r/W_R, where W_R is equal to width of the EI region. Thus, including the information Q that C falls into the EI region in our background information k′ is equivalent to choosing our comparison range as the EI range.

At this point, one might question the legitimacy of including Q in our background information k′: that is, choosing k′ such that k′ → k′ & Q. Besides appealing to examples such as the previously discussed dartboard case, in general when comparing hypotheses, we can place into the background information any evidence that we have good reason to believe neither confirms nor disconfirms the hypothesis in question. In some cases this is obvious: for example, when assessing the ratio of the probabilities of the defendant's fingerprints' matching those on the gun under the guilt and innocence hypothesis, respectively, the fact that Jupiter has over ~~60~~ moons would be irrelevant information. Thus, jurors would be free to include it as part of their background information.

Another way of thinking about this issue is to note that k′ determines the reference class of possible law structures to be used for purposes of estimating the epistemic probability of Lpc under NSU: the probability of Lpc given k′ & NSU is the relative proportion of law structures that are life-permitting in the class of all law structures that are consistent with k′ & NSU. (The measure over this reference class is then given by the restricted Principle of Indifference.) Thinking in terms of reference classes, the justification for restricting our reference class to the EI region is similar to that used in science: when testing a hypothesis, we always restrict our reference classes to those for which we can make the observations and calculations of the frequencies or proportions of interest – what in statistics is called the sample class. This is legitimate as long as we have no reason to think that such a restriction produces a relevantly biased reference class. Tests of the long-term efficacy of certain vitamins, for instance, are often restricted to a reference class of randomly selected doctors and nurses in certain participating hospitals, since these are the only individuals that one can reliably trace for extended periods of time. The assumption of such tests is that we have no reason to think that the doctors and nurses are relevantly different than people who are neither doctors nor nurses, and thus that the reference class is not biased. As discussed in Section 4.2, the justification for varying a constant instead of varying the mathematical form of a law in the fine-tuning argument is that, in the reference class of law structures picked out by varying a constant, we can make some estimate of the proportion of life-permitting law structures. This is something we probably could not do if our reference class involved variations of mathematical form. The same sort of justification underlies restricting the class to the EI range.

It is also important to keep things in perspective by noting that there are really two separate issues here. First is the issue of the existence of a meaningful probability for P(Lpc|Q & k′ & NSU). That question reduces to whether there is an epistemic probability measure over the EI region; this will uncontroversially be the case if the EI region is finite and the restricted Principle of Indifference is true and applies. The second question is whether Q & k′ is the appropriate background information. If one allowed for prior probabilities and the full use of Bayes's Theorem, then any choice is appropriate as long as one also has meaningful prior probabilities for P(NSU|Q & k′), P(T|Q & k′), and P(Lpc|Q & k′ & T).[28] Since I have attempted to avoid the use of prior probabilities, it became important to have some procedure of determining the appropriate background information k′. So this issue arises only for the likelihood version of the argument that avoids prior probabilities. It does not arise for other versions, including the secondary method of probabilistic tension, since, as we saw earlier, that does not depend on the particular choice of appropriate background information.

Including Q in k′ provides a Likelihood Principle reconstruction of John Leslie's "fly on the wall" analogy, which he offers in response to the claim that there could be other unknown values for the constants of physics, or unknown laws, that allow for life:

> If a tiny group of flies is surrounded by a largish fly-free wall area then whether a bullet hits a fly in the group will be very sensitive to the direction in which the firer's rifle points, even if other very different areas of the wall are thick with flies. So it is sufficient to consider *a local area of possible universes,* e.g., those produced by slight changes in gravity's strength. . . . It certainly needn't be claimed that Life and Intelligence could exist *only if* certain force strengths, particle masses, etc. fell within certain narrow ranges. . . . All that need be claimed is that a lifeless universe would have resulted from *fairly minor changes* in the forces etc. with which we are familiar. (1989, pp. 138–9).

Finally, notice how our methodology deals with a common major misunderstanding of the fine-tuning argument based on the constants of physics. On this misunderstanding, advocates of the fine-tuning argument are accused of implicitly assuming the laws somehow existed temporally or logically prior to the constants, and then afterwards the values of the constants were determined. Then one imagines that if NSU is true, the values occur by

28. According to the odds form of Bayes's Theorem, P(NSU|Lpc & k)/P(T|Lpc & k) = P(NSU|Lpc & Q & k′)/P(T|Lpc & Q & k′) = P(NSU|Q & k′)/P(T|Q & k′) × P(Lpc|Q & k′ & NSU)/P(Lpc|Q & k′ & T). [Lpc & Q & k′ = Lpc & k, since (i) Lpc & k′ = k and (ii) the life-permitting range is part of the EI range, and hence Lpc entails Q, which means Lpc & k′ = Lpc & k′ & Q. I am assuming none of the probabilities in the denominators are zero.]

"chance," and hence it is very, very unlikely for them to fall into the life-permitting range. Thus, critics of the fine-tuning argument, such as Ian Hacking (1987, pp. 129–30) and John Earman (2006), have claimed that it begs the question, since it already presupposes the existence of a creator. According to Earman, talk of the existence of a fine-tuned universe's being improbable "seems to presuppose a creation account of actuality: in the beginning there is an ensemble of physically possible universes – all satisfying the laws of our universe but with different values of the constants – awaiting to be anointed with the property of actuality by the great Actualizer . . ." (2006). It should be clear that the way in which I spell out the argument makes no such metaphysical assumption. We simply consider the ratio of epistemic probabilities P(Lpc|T & k′)/P(Lpc|NSU & k′), where Lpc denotes the claim that a constant fell into the life-permitting range; this does not presuppose a creation account of the laws any more than does a likelihood reconstruction of the confirmation that old evidence e provides a scientific theory, in which a similar procedure of subtracting old evidence is involved.[29]

4.5. Examples of the EI region

In this section, we shall consider how to estimate the EI region for the force strengths and some other constants. In doing this, we first note that, as argued in Section 4.2, we must make our estimates of epistemic probability relative to the best calculation-permitting models we have, as long as those models are reasonable approximations of the best current overall models. Consider, for instance, the strong nuclear force, which is only defined in a specific model. We know that this model has only limited applicability since the strong nuclear force is ultimately the byproduct (or residue) of the "color force" between the quarks of which neutrons and protons are composed. Further, the physical model, quantum chromodynamics, describing the color force, is thought to have only limited range of applicability to relatively low energies. Thus, the EI region will be finite, since we can only do valid calculations for those values of the strong nuclear force or color force that stay within a relatively low-energy regime.

This limitation of energy regime does not apply just to the theory of strong interactions, but to all of the fundamental quantum theories of nature. In the past, we have found that physical theories are limited in their range of applicability – for example, Newtonian mechanics was limited to medium-sized objects moving at slow speeds relative to the speed of light. For fast-moving objects, we require special relativity; for massive objects, General Relativity; for very small objects, quantum theory. When the Newtonian limits are violated, these theories predict completely unexpected and seemingly bizarre effects, such as time dilation in special relativity or tunneling in quantum mechanics.

There are good reasons to believe that current physics is limited in its domain of applicability. The most discussed of these limits is energy scale. The current orthodoxy in high-

29. Those, such as McGrew, McGrew, and Vestrup (Section 4.6), who claim that the entire possible range of constants is the only nonarbitrary comparison range, also appear to be in the grip of the mistaken idea that the relevant probabilities are determined by a model of "universe creation" in which first the laws come into existence, and then the constants are "chosen" from the range of possible values that they could have. Since within such a conceptualization, the constants could have had any value, one is erroneously led to think that the only adequate comparison range is minus infinity to plus infinity.

energy physics and cosmology is that our current physics is either only a low-energy approximation to the true physics that applies at all energies or only the low-energy end of a hierarchy of physics, with each member of the hierarchy operating at its own range of energies.[30] The energy at which any particular current theory can no longer to be considered approximately accurate is called the *cutoff* energy, although (despite its name) we should typically expect a continuous decrease in applicability, not simply a sudden change from applicability to nonapplicability. In contemporary terminology, our current physical theories are to be considered *effective field theories*. The limitation of our current physics directly affects thought experiments involving changing the force strengths. Although in everyday life we conceive of forces anthropomorphically as pushes or pulls, in current physics forces are conceived of as interactions involving exchanges of quanta of energy and momentum.[31] The strength of a particular force, therefore, can be thought of as proportional to the rate of exchange of energy-momentum, expressed quantum mechanically in terms of probability cross sections. Drastically increasing the force strengths, therefore, would drastically increase the energy-momentum being exchanged in any given interaction. Put another way, increasing the strength of a force will involve increasing the energy at which the relevant physics takes place. So, for instance, if one were to increase the strength of electromagnetism, the binding energy of electrons in the atom would increase; similarly, an increase in the strength of the strong nuclear force would correspond to an increase in the binding energy in the nucleus.[32]

The limits of the applicability our current physical theories to below a certain energy scales, therefore, translates to a limit on our ability to determine the effects of drastically increasing a value of a given force strength – for example, our physics does not tell us what would happen if we increased the strong nuclear force by a factor of $10^{1,000}$. If we naively applied current physics to that situation, we should conclude that no complex life would be possible because atomic nuclei would be crushed. If a new physics applies, however, entirely new and almost inconceivable effects could occur that make complex life possible, much as quantum effects make the existence of stable atomic orbits possible, whereas such orbits were inconceivable under classical mechanics. Further, we have no guarantee that the concept of a force strength itself remains applicable from within the perspective of the new physics at such energy scales, just as the concept of a particle's having a definite position and momentum, lost applicability in quantum mechanics; or the notion of absolute time lost validity in special relativity; or gravitational "force" (versus curvature of space-

30. See, for instance, Zee (2003, pp. 437–8), Cao (1997, pp. 349–53), and Teller (1988, p. 87). For example, Zee says that he espouses "the philosophy that a quantum field theory provides an effective description of physics up to a certain energy scale Λ, a threshold of ignorance beyond which physics not included in the theory comes into play" (p. 438).

31. Speaking of gravitational force as involving energy exchange is highly problematic, although speaking of gravitational binding energy is not nearly as problematic. One problem is that in General Relativity, gravity is not conceived of as a force but as curvature of space-time. Another problem is that there is no theoretically adequate definition for the local energy of a gravitational field or wave. (See, for instance, Wald, 1984, p. 70, n. 6; p. 286.) Finally, although physicists often speak of gravitons as the carriers as the carrier of the gravitational force, the quantum theory of gravity out of which gravitons arise is notoriously non-renormalizable, meaning that infinities arise that cannot be eliminated. Nonetheless, since gravitational waves cause changes in the energy of material objects at a certain rate, we can still meaningfully speak of energy scales at which a particular gravitational "force" is operating, which is all that is needed for this argument.

32. The weak force does not involve binding energies but is an interaction governing the transmutation of particles from one form to another, and so this last argument would not apply to it.

time) in General Relativity.[33] Thus, by inductive reasoning from the past, we should expect not only entirely unforeseen phenomena at energies far exceeding the cutoff, but we even should expect the loss of the applicability of many of our ordinary concepts, such as that of force strength.

The so-called Plank scale is often assumed to be the cutoff for the applicability of the strong, weak, and electromagnetic forces. This is the scale at which unknown quantum gravity effects are suspected to take place thus invalidating certain foundational assumptions on which current quantum field theories are based, such a continuous space-time (see e.g. Peacock 1999, p. 275; Sahni & Starobinsky 1999, p. 44). The Plank scale occurs at the energy of 10^{19} GeV (billion electron volts), which is roughly 10^{21} higher than the binding energies of protons and neutrons in a nucleus. This means that we could expect a new physics to begin to come into play if the strength of the strong force were increased by more than a factor of $\sim 10^{21}$. Another commonly considered cutoff is the grand unified theory (GUT) scale, which occurs around 10^{15} GeV (Peacock 1999, pp. 249, 267). The GUT scale is the scale at which physicists expect the strong, weak, and electromagnetic forces to be united. From the perspective of the currently proposed GUT, these forces are seen as a result of symmetry-breaking of the united force that is unbroken above 10^{15} GeV, where a new physics would then come into play. Effective field theory approaches to gravity also involve General Relativity's being a low-energy approximation to the true theory. One common proposed cutoff is the Plank scale, although this is not the only one (see e.g. Burgess 2004, p. 6).

Where these cutoffs lie and what is the fundamental justification for them are controversial issues. The point of the previous discussion is that the limits of our current theories are most likely finite but very large, since we know that our physics does work for an enormously wide range of energies. Accordingly, if the life-permitting range for a constant is very small in comparison, then $W_r/W_R \ll 1$, which means that there will be fine-tuning. Rigorously determining W_r/W_R is beyond the scope of this chapter. Almost all other purportedly fine-tuned constants also involve energy considerations: for example, because of Einstein's $E = mc^2$, the rest masses of the fundamental particles (which are fundamental constants) are typically given in terms of their rest energies – for example, the mass of the proton is 938 MeV (million electron volts). Further, the cosmological constant is now thought of as corresponding to the energy density of empty space. Thus, the considerations of energy cutoff mentioned will play a fundamental role in defining the EI region, and hence W_R, for many constants of physics.

4.6. Purported problem of infinite ranges

Finally, let us suppose that the comparison range is infinite, either because of some new theory that applies at all energy scales or because the reasoning in the last two subsections is incorrect. Timothy McGrew, Lydia McGrew, and Eric Vestrup (2001) and, independently, Mark Colyvan, Jay Garfield, and Graham Priest (2005) have argued that if the comparison range is infinite, no meaningful probability can be assigned to a constant's landing in

33. More generally, since constants are only defined with respect to the theories of physics in which they occur, their range of applicability, and thus the EI range, is restricted to the range of applicability of those theories.

the life-permitting region. (They also mistakenly assume that the only nonarbitrary comparison range for the constants of nature consists of all possible values ($-\infty$ to ∞).) These authors first assert that (i) the total probability of a constant's being somewhere in the infinite range of possible values has to be 1 (since it must have some value), and (ii) if we assume an equiprobability distribution over the possible values – which they claim is the only nonarbitrary choice – the probability of its being in any finite region must be zero or undefined. Finally, (iii) they consider any arbitrary way of dividing up the entire range into a countably infinite set of finite, nonoverlapping regions, and assert that the total probability of its being in the entire region must the sum of the probabilities of its being in each member of the set. For example, the probability of its being in the entire region is the sum of the probabilities of its being between 0 and 1, of its being between 1 and 2, of its being between 2 and 3, *ad infinitum*, plus the sum of the probabilities of its being between 0 and –1, between –1 and –2, *ad infinitum.* But since no matter how many times one adds zero together, one gets zero, this sum turns out to be zero. Hence, if we assume that each probability is zero, we get a contradiction since the probability of the constant having a value somewhere in the entire region is 1. Therefore, it must be undefined.

The problem with this argument is the assumption that the epistemic probability for the entire region is the sum of the individual probabilities of each finite disjoint region. In cases where the number of alternatives is finite, this is true: the sum of the probabilities of a die landing on each of its sides is equal to the probability of the die landing on some side. This is a fundamental principle of the probability calculus called *finite additivity*. When finite additivity is extended to a countably infinite number of alternatives, it is called *countable additivity*, which is the principle that McGrew and Vestrup implicitly invoke.

This latter principle, however, has been very controversial for almost every type of probability, with many purported counterexamples to it. Consider, for example, the following situation. Suppose that what you firmly believe to be an angel of ~~“~~God~~”~~ tells you that the universe is infinite in extent and that there are a countably infinite number of other planets with civilizations on each planet. Finally, the “angel” tells you that within a billion miles of one and only one of those planets is a golden ball 1 mile in diameter and that it has delivered the ~~same~~ identical message to one person on each of those planets. Finally, you decide on the following arbitrary numbering system to identify the planets: you label Earth 1, the planet that is closest to Earth 2, the planet that is next farther out 3, and so forth. Since within current Big Bang cosmology an infinite universe would have no center, there is nothing special about Earth's location that could figure into one's probability calculation. Accordingly, it seems obvious that, given that you fully believe the angel, for every planet k your confidence that the golden ball is within a billion miles of k should be zero. Yet this probability distribution violates countable additivity. One cannot argue that the scenario I proposed is in any way self-contradictory, unless one wants to argue that an infinite universe is self-contradictory. This, however, ends up involving substantive metaphysical claims and is arguably irrelevant, since the issue is the degree to which the propositions delivered by the angel justifies, or warrants, the belief that the ball is ~~not~~ within a billion miles of our planet, not whether these propositions ultimately could be true.

McGrew and McGrew (2005) have responded to these sorts of arguments by claiming that when the only nonarbitrary distribution of degrees of belief violates the axiom of countable additivity, the most rational alternative is to remain agnostic. They point out that one need not assign epistemic probabilities to all propositions. I do not believe this is an adequate response, since I think in some cases it would be irrational to remain agnostic. For example, it would be irrational for a billionaire who received the aforementioned message to spend millions, or even hundreds, of dollars in search of the golden planet, even if it were entirely rational for him to believe what the angel told him; it would even be irrational for him to hope to discover the planet. This is radically different than cases where people are legitimately agnostic, such as perhaps about the existence of extraterrestrials or the existence of God; for example, it seems rationally permitted at least to hope for and seek evidence for the existence of extraterrestrials or God.

The implausibility of being agnostic in the "golden planet case" is further brought out when one considers that if the billionaire were told that the universe was finite with exactly $10^{10,000}$ planets with civilizations, clearly he should be near certain that the golden planet is not near Earth. But, clearly, if the billionaire is told that there are even more planets – infinitely many – the billionaire should be at least as confident that the planet is not near Earth; and, certainly, it should not become more rational for him to search for it than in the $10^{10,000}$ planets case, as it would if he should switch to being agnostic.

So the McGrews and others are wrong in claiming that there would be no epistemic probability if the range is infinite. However, they are correct in claiming that this would turn the fine-tuning argument into what McGrew, McGrew, and Vestrup (2001) have called *the course-tuning argument* (CTA). As they correctly point out, if the comparison range is infinite, then no matter how large the life-permitting range is, as long as it is finite the ratio W_r/W_R will be zero. This means that the narrowness of the range becomes irrelevant to our assessment of degree of fine-tuning. The McGrews and Vestrup, reiterating a point made by Paul Davies (1992, pp. 204–5), claim that it is obvious that CTA is not a good argument since CTA would have the same force no matter how "un-fine-tuned" a constant is, as long as the life-permitting range is finite. Thus, they argue, this would render the appeal to physics, and the narrowness of the life-permitting range, completely superfluous.

In response, an appeal to physics would still be necessary: we still should have to have good physical reasons to think the life-permitting range to be finite, which itself would involve having a model that we had good reasons to believe was accurate for all values of the parameter in question. This would involve a substantial appeal to physics. Of course, if it turned out that the comparison range were infinite, the restrictiveness of the life-permitting range would no longer play a role, and thus the popular presentation of the argument would have to be modified. Nonetheless, the formal presentation of the argument, based on the claim that $W_r/W_R \ll 1$ and the restricted Principle of Indifference, would remain. As is, I suggest that the reason we are impressed with the smallness is that we actually do have some vague finite comparison range to which we are comparing the life-permitting range, namely the EI range.

Finally, rejecting CTA for the reasons the McGrews and Vestrup give is counterintuitive. Assume that the fine-tuning argument would have probative force if the comparison range were finite. Although they might not agree with this assumption, making it will allow us to consider whether having an infinite instead of finite comparison range is relevant to the cogency of the fine-tuning argument. Now imagine increasing the width of this comparison range while keeping it finite. Clearly, the more W_R increases, the stronger the fine-tuning argument gets. Indeed, if we accept the restricted Principle of Indifference (Section 3.32), as W_R approaches infinity, $P(Lpc|NSU \& k')$ will converge to zero, and thus $P(Lpc|NSU$

& k′) = 0 in the limit as W_R approaches infinity. Accordingly, if we deny that CTA has probative force *because* W_R is purportedly infinite, we must draw the counterintuitive consequence that although the fine-tuning argument gets stronger and stronger as W_R grows, magically when W_R becomes actually infinite, the fine-tuning argument loses all probative force.[34]

5. Justifying Premises (1) and (2)

5.1. Justifying premise (1)

The justification of Premise (1) of our main argument in Section 1.3 will depend on which fine-tuned feature of the universe is being considered. For the fine-tuning of the laws of nature, Premise (1) would be justified by an appeal to widely shared intuitions, as explained in Section 3.3.1. For the fine-tuning of the initial conditions of the universe, we have two choices. First, we could appeal to the standard measure of statistical mechanics (as is typically done). Second, if we have qualms about the applicability of the standard measure discussed in Section 2.4, we could appeal to the compelling reasons given in that section for thinking that the universe started in an extraordinarily special state; hence, in some real sense it is still epistemically enormously improbable, even if we cannot provide a rigorous mathematical grounding for that probability.

Finally, for the fine-tuning of the constants of physics, we shall appeal to the restricted Principle of Indifference (Section 3.3.2). This is the case we shall elaborate in detail. We shall begin by justifying Premise (1) for the case of individual constants that are fine-tuned and then consider the case in which the constants are combined. The argument has two steps:

(i) Let C be a constant that is fine-tuned, with C occurring in the simplest current formulation of the laws of physics. Then, by the definition of fine-tuning, $W_r/W_R \ll 1$, where W_r is the width of the life-permitting range of C, and W_R is the width of the comparison range.

(ii) Since NSU and k′ give us no reason to think that the constant will be in one part of the EI range instead of any other of equal width, and k′ contains the information that it is somewhere in the EI range, it follows from the restricted Principle of Indifference that $P(Lpc|NSU \& k') = W_r/W_R$, which implies that $P(Lpc|NSU \& k') \ll 1$.

5.1.2. Combining constants

Some have faulted the fine-tuning arguments for only varying one constant at a time, while keeping the values of the rest fixed. For example, Victor Stenger claims that, "One of the many major flaws with most studies of the anthropic coincidences is that the investigators vary a single parameter while assuming all the others remain fixed!" (2007, p. 148).

34. For an argument showing that various inferences in contemporary cosmological speculation use infinite ranges, and for some mathematical justification of these, see Koperski (2005).

This issue can be easily addressed for a case in which the life-permitting range of one constant, C_1, does not significantly depend on the value that another constant, C_2, takes within its comparison range, R_2. In that case, the joint probability of *both* C_1 and C_2 falling into their life-permitting ranges is simply the product of the two probabilities. To see why, note that by the method explicated in Sections 4.3 and 4.4, the appropriate background information, k'_{12}, for the joint conditional probability of Lpc_1 & Lpc_2 on NSU is $k'_{12} = k - Lpc_1$ & $Q_1 - Lpc_2$ & $Q_2 = k'_1$ & k'_2. Here, $-Lpc_1$ and the $-Lpc_2$ represent the subtraction of the information that C_1 and C_2 have life-permitting values, respectively; Q_1 and Q_2 represent, respectively, the knowledge that they each fell into their respective EI regions (which is added back in, as explained in Section 4.4); and $k'_1 = k - Lpc_1$ & Q_1 and $k'_2 = k - Lpc_2$ & Q_2 represent the appropriate background information for C_1 and C_2, respectively, when they are considered separately.

By the definition of conditional probability, $P(Lpc_1 \,\&\, Lpc_2|NSU \,\&\, k'_{12}) = P(Lpc_1|NSU \,\&\, k'_{12} \,\&\, Lpc_2) \times P(Lpc_2|NSU \,\&\, k'_{12})$. Now, Q_2 & $Lpc_2 = Lpc_2$ since the claim that C_2 fell into its (known) life-permitting region entails that it fell into its EI region: that is, $Lpc_2 \rightarrow Q_2$. Hence, $k'_{12} \,\&\, Lpc_2 = k - Lpc_1 \,\&\, Q_1 - Lpc_2 \,\&\, Q_2 \,\&\, Lpc_2 = k - Lpc_1 \,\&\, Q_1 - Lpc_2 \,\&\, (Q_2 \,\&\, Lpc_2) = k - Lpc_1 \,\&\, Q_1 - Lpc_2 \,\&\, Lpc_2 = k - Lpc_1 \,\&\, Q_1 = k'_1$. It follows, therefore, that $P(Lpc_1|NSU \,\&\, k'_{12} \,\&\, Lpc_2) = P(Lpc_1|NSU \,\&\, k'_1)$, which was merely the probability we calculated for Lpc_1 on the background information in which we held all the other constants fixed. So, our next question is, what is the value of $P(Lpc_2|NSU \,\&\, k'_{12})$? Now, k'_{12} includes the values of all the other constants besides C_1 and C_2. For C_1 and C_2 it only includes the information that they are in their respective EI regions. Thus, if the width, W_{r2}, of the life-permitting range of C_2 is not significantly dependent on the value of C_1 in C_1's EI region, then by the restricted Principle of Indifference, $P(Lpc_2|NSU \,\&\, k'_{12}) \sim W_{r2}/W_{R2} = P(Lpc_2|NSU \,\&\, k'_2)$, where W_{R2} is the width of EI region for C_2 when all other constants are held fixed.[35] This means that $P(Lpc_1 \,\&\, Lpc_2|NSU \,\&\, k'_{12}) \sim P(Lpc_1|NSU \,\&\, k'_1) \times P(Lpc_2|NSU \,\&\, k'_2)$. *Thus, we can treat the two probabilities as effectively independent.*

When will two constants be independent in this way? Those will be cases in which the factors responsible for C_1's being life-permitting are effectively independent of the factors responsible for C_2's being life-permitting. For example, consider the case of the fine-tuning of the cosmological constant (C_1) and the fine-tuning of the strength of gravity (C_2) relative to the strength of materials – that is, the first case of the fine-tuning of gravity discussed in Section 2.3.2. The life-permitting range of gravity as it relates to the strength of materials does not depend on the value of the cosmological constant, and hence $P(Lpc_2|k'_{12} \,\&\, NSU) = P(Lpc_2|k'_2 \,\&\, NSU)$. This means that the joint probability of both gravity and the cosmological constant's falling into their life-permitting ranges is the product of these two probabilities: W_r/W_R for gravity times W_r/W_R for the cosmological constant. This same analysis will hold for any set of fine-tuned constants in which the life-permitting range for each constant is independent of the values the other constants take in their respective EI ranges: e.g., the set consisting of the fine-tuning of the strong nuclear force needed for stable nuclei and the previously discussed example of the fine-tuning of gravity.

35. If W_{r2} is dependent on the value C_1 takes in its EI region, then one would have to take the average value of W_{r2} over C_1's EI region. This would cover those cases for which the two constants are not independent, although we are not considering those cases here. We are also assuming that W_{R2} is not significantly dependent on the value C_1 takes in its EI region; otherwise, we would also have to take the average of W_{R2}.

5.2. Justifying premise (2)

In order to justify Premise (2) of our main argument in Section 1.3, we shall need to argue that God has some reason to bring about LPU.[36] For definiteness, we shall first consider the case of the fine-tuning of the constants under the assumption that T is true and that there is only one universe. That is, we shall attempt to justify the claim that for any constant C that is fine-tuned, ~P(Lpc|TSU & k′) $\ll$ 1, where TSU is the theistic single-universe hypothesis and k′ is the background information defined in Sections 4.3 and 4.4. It should then be clear how this case generalizes to cases in which the constants are combined, and for the two other fundamental types of fine-tuning discussed in Section 2. Finally, we shall indicate how this argument generalizes for a theistic multiverse hypothesis (TMU).

To determine P(Lpc|TSU & k′), let us invoke our imaginative device (Section 3.2) of an unembodied, alien observer with cognitive faculties relevantly similar to our own and who believes TSU and k′. This observer would designate our universe as "the universe that is actual" – which we shall abbreviate as U – and would know that U has the laws that our universe has and the values of all the other constants, except that it only would know that constant C had a value in the EI region. Now if this unembodied being could perceive no reason for God to create the universe with C in the life-permitting region instead of any other part of the EI region, then P(Lpc|TSU & k′) = $W_r/W_R \ll 1$. *So the claim that ~P(Lpc|TSU & k′) $\ll$ 1 hinges on this unembodied being's (and hence our) perceiving some reason why God would create a life-permitting universe over other possibilities.*

As Richard Swinburne has argued (2004, pp. 99–106), since God is perfectly good, omniscient, omnipotent, and perfectly free, the only motivation God has for bringing about one state of affairs instead of another is its relative (probable) contribution to the overall moral and aesthetic value of reality.[37] Simple forms of life, such as bacteria, do not seem in and of themselves to contribute to the overall moral value of reality, although it is possible that they might contribute to its overall aesthetic value. On the other hand, embodied moral agents seem to allow for the realization of unique types of value. Hence, it is this form of life that is most relevant for arguing that ~P(Lpc|k′ & T) $\ll$ 1, and thus the most relevant for the fine-tuning argument.

Now let EMA represent the claim that the universe contains embodied moral agents, and let Wh represent whatever else God must do over and above creating the universe with the right laws, constants, and initial conditions to ensure that it contains such agents, such as God's intervening in the unfolding of the universe. Now P(EMA|TSU & k′) = P(Lpc & Wh|TSU & k′) = P(Wh|Lpc & k′ & TSU) × P (Lpc|TSU & k′), given that these probabilities have well-defined values or ranges of value. Since P(Wh|Lpc & k′ & TSU) ≤ 1, it follows that P(Lpc|TSU & k′) ≥ P(EMA|TSU & k′), once again assuming that these probabilities have well-defined values or ranges of value. Thus, if we can establish that ~P(EMA|TSU & k′) $\ll$ 1, we shall have established that ~P(Lpc|TSU & k′) $\ll$ 1 (which will automatically

36. For the specific case of the fine-tuning argument, this section will answer a major objection that is often raised more generally against the design argument (e.g. by Sober 2005): namely, that for the features F that these arguments appeal to, we have no way of determining the probability of God's creating a world with those features, since we have no way of determining God's desires.

37. "Probable" is parenthetically inserted before "value" here and elsewhere to allow for open theism, in which God cannot predict with certainty human free choices and hence the overall value of reality.

be true if the probabilities are not well defined). In order for $\sim P(EMA|TSU \,\&\, k') \ll 1$, it must be plausible to suppose that on balance, God has more reason to make U in such a way that EMA is true than to make it in such a way that EMA is false. We must be very careful about what is required here. Since we are dealing with epistemic probabilities, which are relative to human cognitive faculties and limitations, to establish that $\sim P(EMA|TSU \,\&\, k') \ll 1$ does not require that we show that God actually has more reason, only that it is plausible to suppose that God does.

This will require first that we perceive, however dimly, that it is plausible to think that the existence of embodied creatures like us – that is, finite, vulnerable, embodied moral agents –has a (probable) overall positive value, thus giving God a reason to create a world in which such beings could come about. One cannot merely argue for the value of personal agents in general. The reason is that God's fine-tuning universe U to make EMA true will result in various forms of moral and natural evil, unless God constantly intervenes to prevent it, which clearly does not happen in our world.[38] Thus, in order for God to have a reason to adjust C so that U contains our type of embodied moral agents, there must be certain compensatory goods that could not be realized, or at least optimally realized, without our type of embodiment. This brings us directly to the problem of evil.

If we have an adequate theodicy, then we could plausibly argue that our unembodied alien observer would have positive grounds for thinking that God had more reason to create the universe so that EMA is true, since it would have good reason to think that the existence of such beings would add to the overall value of reality. In that case, we could argue that $P(Lpc|TSU \,\&\, k') > 0.5$.[39] On the other hand, if we have no adequate theodicy, but only a good defense – that is, a good argument showing that we lack sufficient reasons to think that a world such as ours would result in more evil than good – then our unembodied being would both lack sufficient reason to expect that God would make U so that EMA would be true and lack sufficient reason to expect God to create U so that EMA would be false. Hence, there would be no conditional epistemic probability of EMA on TSU & k′ and therefore no conditional epistemic probability for $P(Lpc|TSU \,\&\, k')$. It would still follow, however, that Lpc is not epistemically improbable under TSU: that is, $\sim P(Lpc|TSU \,\&\, k') \ll 1$. Hence, Lpc would still give us good reason to believe TSU over NSU.[40]

38. I would like to thank Paul Draper for making me aware of the need to address the problem of evil as part of the fine-tuning argument. (See Draper 2008.)

39. One such theodicy (Collins, unpublished manuscript) that I believe explains much of the evil in the world is what I call the "connection building theodicy," in which the greater goods are certain sorts of deep eternal, ongoing relations of appreciation and intimacy created by one person's helping another – for example, out of moral and spiritual darkness, in times of suffering, and so on.

40. One might challenge this conclusion by claiming that both the restricted Likelihood Principle and the method of probabilistic tension require that a positive, known probability exist for Lpc on T & k′. This seems incorrect, as can be seen by considering cases of disconfirmation in science. For example, suppose some hypothesis h conjoined with suitable auxiliary hypotheses, A, predict e, but e is found not to obtain. Let ~E be the claim that the experimental results were ~e. Now, $P(\sim E|h \,\&\, A \,\&\, k) \ll 1$, yet $P(\sim E|h \,\&\, A \,\&\, k) \neq 0$ because of the small likelihood of experimental error. Further, often $P(\sim E|\sim(h \,\&\, A) \,\&\, k)$ will be unknown or indeterminate, since we do not know all the alternatives to h ~~or~~ what they predict about e. Yet, typically we would take ~E to disconfirm h & A in this case because $P(\sim E|h \,\&\, A \,\&\, k) \ll 1$ and $\sim P(\sim E|\sim(h \,\&\, A) \,\&\, k) \ll 1$.

Thus, unless the atheist can show that it is highly improbable that God would create a world which contained as much evil as ours, it will still be the case that, given the evidence of the fine-tuning of the constants, the *conjunction* of the existence of evil and the fact that the constants have life-permitting values strongly confirms TSU over NSU. This means that theism is still confirmed when the strongest evidence that atheists typically offer for their position (i.e. the existence of evil) is combined with the evidence of the fine-tuning of the constants. Specifically, if we let Ev denote the existence of the kinds and degrees of evil we find in the world, then, for all fine-tuned constants C, Lpc & Ev gives us good reason to believe in TSU over NSU.[41]

What about the case of ~~the~~ TMU – that is, the hypothesis that God exists and created many universes. One possibility is to consider the evidence, Lpc*, where Lpc* = "the value of the constant C of *this* universe falls into the life-permitting range," where "this universe" refers to our universe by some means other than "the one and only actual universe": for example, by means of some sort of indexical, such as "the universe that contains *this* electron," where the unembodied being has some way of referring to "this electron" other than by a definite description that uses only purely qualitative properties. Now, some might worry here that given the existence of multiple universes, God would have no reason to make this universe life-permitting, and thus that $P(Lpc^*|TMU \& k') \ll 1$. For example, Roger White claims that, "It is only the assumption that there are no other options that we should expect the designer to fine-tune *this* universe for life" (2000, p. 243). I disagree. Given that the existence of our type of embodied moral agents is a (probable) overall good, it would contribute to the overall value of reality even if there were such beings in other universes. Thus, God would still have a reason for fine-tuning this universe, and hence $\sim P(Lpc^*|TMU \& k') \ll 1$. Yet, $P(Lpc^*/NSU \& k') = P(Lpc/NSU \& k') \ll 1$, and hence Lpc* would confirm TMU over NSU.

Even if White is correct, however, our unembodied alien would still have the same reason as offered earlier for thinking that God would create *some* life-permitting universe. Thus, $\sim P(LPU^*|TMU \& k') \ll 1$, where LPU* is the claim that "some life-permitting universe exists." Nonetheless, since for every constant C, NSU & k′ & LPU* entails Lpc & NSU & k′, $P(LPU^*|NSU \& k') \leq P(Lpc|NSU \& k') \ll 1$. Thus, by the restricted version of the Likelihood Principle, LPU* confirms TMU over NSU. If White is right, therefore, the relevant confirmatory evidence for TMU versus NSU would become "some life-permitting universe exists" instead of "this universe has life-permitting values for its constants."

6. The Multiverse Hypothesis

6.1. Introduction

The multiverse hypothesis is the hypothesis that there exist many regions of space-time – that is, "universes" – with different initial conditions, constants of physics, and even laws of nature. It is commonly considered the major alternative to the competing hypotheses

41. Finally, in a worst-case scenario in which an atheist offered good reason to believe that Ev is unlikely under T, it would still probably be the case that Lpc & Ev would disconfirm NSU over TSU, not only because the improbability of Lpc is so great under NSU that it would be less than $P(Ev|TSU \& k')$ but also because $P(Lpc|NSU \& k') \ll 1$ receives a principled justification – via the restricted Principle of Indifference – whereas the arguments offered for $P(Ev|T \& k) \ll 1$ are typically based on highly controversial intuitions.

of T and NSU. Just as in a lottery in which all the tickets are sold, one is bound to be the winning number, so given a varied enough set of universes with regard to some life-permitting feature F, it is no longer surprising that there exists a universe somewhere that has F. Multiverse hypotheses differ both in the features that vary from universe to universe – for example, the initial conditions, the constants of physics, and so on – and what physical process, if any, produced them.

The multiverse objection can be interpreted as either claiming that the multiverse provides an alternative explanation of the fine-tuning of the cosmos, or that it simply eliminates the epistemic improbability of the fine-tuning. We shall focus primarily on the latter objection, since such an objection would undermine any argument based on the Likelihood Principle that the fine-tuning provides evidence for T over a naturalistic version of the multiverse hypothesis. Put precisely, this version of the multiverse objection is that $\sim P(LPU|NMU \& k') \ll 1$, where k′ is some appropriately chosen background information and NMU is the relevant naturalistic multiverse hypothesis. Thus, it is claimed, LPU does not provide evidence via the Likelihood Principle for T over an appropriately chosen multiverse hypothesis.

To address this objection, we first need to get clear on exactly how multiverse hypotheses are supposed to explain, or take away the seeming improbability of, the fine-tuning. To begin, we need to distinguish between three facts with regard to the fine-tuning that are candidates for explanation: (1) what I call the *observer-relative* life-permitting (LP) fact that we, or I, observe a life-permitting universe instead of a non-life-permitting universe; (2) what I call the *indexical* LP fact that *this* universe is life-permitting – or has some life-permitting feature F, where "this" is an indexical that picks out the universe we inhabit; and (3) what I call the *existential* LP fact that a life-permitting universe exists, a fact that is equivalent to what we have been referring to by "LPU". The so-called *Weak Anthropic Principle*, which states that the universe we inhabit must have a life-permitting structure, appears to be enough to make the observer-relative LP fact unsurprising. With regard to the indexical LP fact, some philosophers claim that we cannot make a purely indexical reference to our universe but can only refer to our universe via an implicit description. Thus, for instance, one could claim that "this universe" is reducible to "the universe we inhabit," where the "we" is in turn reducible to some other description such as "conscious observers with characteristics X," where X refers to some set of purely qualitative properties. If this analysis is correct, then the claim that "this universe is life-permitting" would be a tautology, and hence have an epistemic probability of one. Even if one rejected this analysis, one could still claim that the life-permitting character of our universe is a defining, or at least an essential, feature of it, so the indexical LP fact is a necessary truth and thus not surprising. Consequently, it is questionable whether this indexical fact is in any way improbable. In any case, it is clear that the multiverse hypothesis does not itself explain or render probable this indexical LP fact, since whether or not other universes exist is irrelevant to the features *our* universe might have.

So the only place where the multiverse hypothesis could help in explaining the fine-tuning or undercutting its improbability is by explaining or undercutting the apparent improbability of LPU – that is, of the existential LP fact expressed by (3). A hypothesis postulating a sufficiently varied multiverse will entail LPU; hence, purportedly it will not only explain why some such universe exists but will also undercut any claim that the existence of such a universe is improbable. It is here, and only here, that the multiverse could do any work in undercutting the fine-tuning argument for T. The so-called observer-selection effect, often considered an essential part of the multiverse explanation, does not itself contribute at all; this effect only explains the observer-relative LP fact given by (1) and is already taken into account by the Weak Anthropic Principle.

Now it is important to distinguish between two categories of multiverse hypotheses: the *unrestricted* version (which I shall label UMU) and various types of *restricted* versions. The unrestricted version is the hypothesis that all possible worlds exist, a version famously advocated by philosopher David Lewis as an account of modal claims. According to Lewis, every possible world actually exists (as a region of space-time) parallel to our own. Thus, for instance, there exists a reality parallel to our own in which objects can travel faster than the speed of light. Dream up a possible scenario, and it exists in some parallel reality, according to Lewis. These worlds, however, are completely isolated from ours, and there are no spatiotemporal or causal relations between the worlds – for example, things in one world do not happen before, at the same time, or after things in our world. Further, they do not overlap in any way, except for the possibility of sharing immanent universals. (1986, p. 2).

Lewis advocates his hypothesis as an account of modal statements – that is, statements that make claims about possibility and impossibility, such as "it is possible that Al Gore won the US presidential election in 2004," and "it is impossible for an object to be a perfect cube and a perfect sphere at the same time." Thus, Lewis calls his view modal realism, with the term "realism" indicating that every possible world exists in as real a way as our own. This term, however, is a misnomer, since it implies that other accounts of modal claims are antirealist, which they are not. The other major advocate of a similar view is Massachusetts Institute of Technology astrophysicist Max Tegmark (1998, 2003). According to Tegmark, "everything that exists mathematically exists physically" (1998, p. 1), by which he means that every self-consistent mathematical structure is in one-to-one correspondence with some physical reality (1998, pp. 1–3). Unlike Lewis, Tegmark's primary argument for his view is to explain LPU. Further, it is unclear whether Tegmark is claiming that every possible universe exists, or only that every possible universe that can be described purely mathematically; in the latter case it would not be a completely unrestricted multiverse hypothesis.

In contrast to Lewis's and perhaps Tegmark's hypothesis, restricted multiverse hypotheses postulate some restriction on the possible universes (or worlds) that actually exist. The most widely discussed versions are those that claim that a multitude of varied universes are generated by some physical process (what I will call a "multiverse generator"). We shall discuss these in Section 6.3. The important point here is that such a restriction will run the danger of reinstantiating the problem of fine-tuning at the level of the restrictions placed on the set of existing universes. In Section 6.3, I shall argue in detail that this is what happens in the case of the most widely discussed multiverse-generator hypothesis, the inflationary-superstring multiverse hypothesis.

Unlike the restricted versions of the multiverse hypothesis, the unrestricted version does not run any danger of reinstantiating the problem of fine-tuning. As I shall argue in the next subsection, however, it faces the following devastating dilemma as an alternative to a theistic explanation of the fine-tuning: *it either undercuts almost all scientific reasoning and ordinary claims of improbability, or it completely fails to undercut the fine-tuning argument for T.*[42]

42. Here, I am simply making rigorous an argument suggested by others, such as William Lane Craig (2003, p. 173) and cosmologist Robert Mann (2005, pp. 308–9).

6.2. Critique of the unrestricted multiverse

To begin our argument, consider a particular event for which we would normally demand an explanation, say, that of Jane's rolling a six-sided die 100 times in a row and its coming up on six each time. Call the type of sequence "coming up 100 times on six" type Tx. Further, let "D" denote the particular die that Jane rolled and DTx the state of affairs of D's falling under type Tx for the particular sequence of die rolls: that is, DTx is the state of affairs of D's coming up 100 times in a row on six for that particular sequence of die rolls. Normally, we should not accept that DTx simply happened by chance; we should look for an explanation. The reason is that DTx is *both* very improbable, having a one in 6^{100} chance of occurring, and in some way "special." The quality of being "special" is necessary for our seeking an explanation since all 100 sequences of rolls are equally improbable, but they are not all in need of an explanation. In general, what makes an improbable occurrence special, and thus a *coincidence* in need of explanation, is difficult to explicate precisely. John Leslie, for example, has proposed that this specialness consists of our being able to glimpse a simple, unified explanation of the occurrence (Leslie, 1988, p. 302). In whatever way one explicates being "special," however, certainly, a six-sided die coming up 100 times in a row on six qualifies.

Now, for any possible state of affairs S – such as DTx – UMU entails that this state of affairs S is actual. Thus, with regard to explanation, for all possible states of affairs S, advocates of UMU must claim that the fact that UMU entails S either (i.a) undercuts all need for explanation, or (i.b) it does not. Further, with regard to some state of affairs S (such as DTx) that we normally and uncontroversially regard as improbable, they must claim that the fact that UMU entails S either (ii.a) undercuts the improbability of S (since it entails S), or (ii.b) it does not. Both (i.a) and (ii.a) would constitute a *reductio* of UMU, since it would undercut both all justifications in science based on explanatory merits of an hypothesis and ordinary claims of probability, such as in our die example. If advocates of UMU adopt (i.b) and (ii.b), however, then the mere fact that UMU entails LPU undercuts neither the need to explain LPU nor its apparent improbability.[43]

Part of what gives rise to the temptation to think that UMU can explain, or render unsurprising, LPU (without doing the same for every other occurrence) is the existence of other "many-trials" scenarios that appear to be analogous but which are really crucially disanalogous. The way in which they are disanalogous is that they only entail the occurrence of a very limited number of states of affairs that we find highly surprising, without entailing the existence of all such states of affairs. What drives inferences of epistemic probability these cases is what I call the *Entailment Principle*. This principle states that if h & k′ is *known* to entail S, or *known* to render the statistical probability of S near 1, then the conditional epistemic probability of S on h & k′ is near 1: that is, P(S|h & k′) ~ 1.[44] For limited multiple-trial hypotheses the Entailment Principle can render epistemically

43. Lewis (1986, pp. 131–2) explicitly adopts (i.b).

44. In standard presentations of the logical and subjective accounts of conditional probability, the fact that h & k′ entails S is sufficient to render P(S|h & k′) = 1, whether or not we know that h & k′ entails S. The account of epistemic probability that I developed in Section 3.2, however, ~~makes~~ probability relative to human cognitive limitations. Thus, the fact that h & k′ entails S would only make P(S|h & k′) = 1 if we knew that fact.

probable the actuality of some state of affairs whose actuality would otherwise be considered highly improbable, without at the same time rendering the actuality of other states of affairs probable that we normally consider improbable. Consider, for example, what could be called the multiple-die-roll hypothesis (MDR), according to which an enormous number of dice are being rolled at every moment throughout the galaxy, in fact so many that the statistical probability that some sequence of 100 die rolls will come up all sixes is almost one. By the Entailment Principle, it follows that it is highly epistemically probable under MDR that *some* 100-member sequence of die rolls will come up all sixes. The conjunction of MDR and the Entailment Principle, however, does not change the probability of other states of affairs whose improbability is critical for everyday inferences, such as some particular sequence of die rolls coming up all sixes.

Now, advocates of UMU could affirm the Entailment Principle and still retain the claim that for some states of affairs S, the actuality of S is epistemically improbable under UMU. As we saw earlier, if S is a possible state of affairs, then UMU entails that S is actual. If we can know that S is possible without knowing that S is actual, then the claim that S is possible would be part of our background information k′, and hence P(S|UMU & k′) = 1. Suppose that for some cases, however, we cannot know whether S is possible apart from S's actually occurring. In those cases, the Entailment Principle could be true and yet for some S, P(S|UMU & k′) < 1, even though UMU entails S. In the case of the die D in our earlier example, the particular die D exists only as part of the world W it occupies, and thus the only possible sequence of rolls of D are those that it has in W.[45] Consequently, unless we know the sequences of rolls of D that have actually occurred in W, we cannot know whether it is *possible* for D to fall in sequence type Tx without knowing whether D has *actually* fallen in type Tx. This means that even though UMU might entail that D lands in type Tx, we could not deduce this from UMU, and, hence, the conditional epistemic probability of D's falling in Tx could be less than 1. The epistemic probability of P(DTx|k′ & UMU) would then be given by the degree to which k′ & UMU of itself rationally justifies the proposition, DTx, that die D came up in sequence type Tx. Call this the *nondeducibility loophole*, since it arises from the fact that even though UMU entails the actuality of all actual states of affairs S, we cannot always *derive* S's actuality from UMU.

Now the nondeducibility loophole will work only if we can refer to D in W in a way that is not equivalent or reducible to providing some qualitative description that uniquely picks it out from among all dice that exist across worlds, since such a qualitative description would have to include everything about D that distinguishes it from its counterparts in other worlds, including DTx, or ~DTx. ~~That is,~~ only if we can make statements about the die that *essentially* involve the use of indexicals – that is, involve the use of indexicals, such as "this die," in a way that cannot be translated in terms of statements that only use qualitative descriptions such as "the die with properties P," where the properties P are purely qualitative properties.[46]

45. Of course, Lewis would want to affirm the ordinary claim that it possible for D to land in a different sequence than it actually does in world W. He would interpret that ordinary claim, however, as really saying that there are certain relevantly similar counterparts to D in other worlds that landed in a different sequence, not that it was possible for the *particular die D* to have landed differently.

46. It is hard to see how such essentially indexical claims are possible under UMU, since such claims seem to imply unrealized alternative possibilities, which would contradict UMU. For example, if die D is not defined by the conjunction of all its qualitative properties, then it seems that it could have had different qualitative properties, such as landing on a different sequence of numbers.

If we allow such essentially indexical propositions about particular objects in the universe, such as the die, then it seems we can also make such essentially indexical statements about the universe we inhabit: we could simply specify that universe U (or "this universe") refers to the universe that contains some particular object – for example, some particular electron – that we are referring to in an essentially indexical manner. This will allow us to adopt the same loophole to the Entailment Principle as adopted by advocates of UMU. Put differently, what I called the *indexical LP fact* – that is, the fact that universe U is life-permitting – could no longer be simply dismissed as needing no explanation (or lacking improbability) because it is purportedly a defining or essential feature of this universe that it is life-permitting. The reason is that even though it would be an essential feature of this universe, we could not deduce it from UMU without already knowing that it is possible for universe U to be life-permitting, just as we could not deduce DTx from UMU without knowing that DTx is possible.

Finally, to exploit the nondeducibility loophole for the indexical LP fact, we simply apply our standard procedure for subtracting out old evidence – such as that the universe has life-permitting values for its constants – to obtain background information k′. Now, although k′ and UMU entail that universe U is life-permitting, a being with cognitive faculties relevantly similar to our own could not deduce that simply by knowing k′ and UMU: for example, if our unembodied being introduced at the end of Section 3.2 were given the information k′ and UMU, it would not know whether U was life-permitting or not. Consequently, by the same argument used for the case of the NSU, P(Universe U is life-permitting|UMU & k′) $\ll$ 1 and P(Lpc|UMU & k′) $\ll$ 1.[47] Of course, one might argue against this subtraction procedure, but this sort of argument is a direct challenge to my version of the fine-tuning argument itself, not a challenge arising from UMU. (See Section 4.3 for a defense of the subtraction procedure.)[48]

A general lesson to be gained from this analysis is that any multiverse hypothesis that purportedly undercuts the fine-tuning argument by entailing LPU will have to be restricted in the right way: specifically, it will have to be such that it does not entail states

47. Further, the probability, P(Lpc|TSU & k′), discussed in Section 5.2 would be unaffected, although now its interpretation would be different: Lpc in both P(Lpc|UMU & k′) and P(Lpc|TSU & k′) would refer to the fact that *this* universe U has a life-permitting value for its constant C instead of the fact that the "universe that is actual" has a life-permitting value, as it did in Sections 5, where Lpc* denoted the former use of Lpc. If we had strong independent reasons for believing in multiple universes (of some sort of restricted variety, not UMU), then we should have to consider whether ~P(Lpc*|TMU & k′) $\ll$ 1 since TSU would no longer be a viable hypothesis. (TMU is the theistic multiverse hypothesis.) See the end of Section 5.2 for brief discussion of ~P(Lpc*|TMU & k′) $\ll$ 1.

48. Lewis could also attempt to appeal to statistical probability in defense of the improbability of DTx by claiming that D should be considered a part of a reference class of all relevantly similar dice in nearby worlds. This, however, opens the door to an advocate of the fine-tuning argument to make a similar claim about the improbability of the fine-tuning of our universe: namely, we should consider our universe part of a reference class of worlds with the same mathematical form for the laws of nature but with constants that are allowed to differ. Then, by the restricted Principle of Indifference, P(Lpc*|UMU & k′) = $W_r/W_R \ll 1$. (See note 47 for definition of Lpc*.)

Another major objection that can be raised against UMU is that the overwhelming majority of worlds are deceptive worlds and worlds in which induction fails. For example, Peter Forrest has argued that there are a vastly greater proportion of worlds in which observers exist with the same past and the same subjective experiences as ours, but in which the future does not in any way resemble the past. Purportedly, this raises an enormous skeptical problem for UMU. I tend to agree with Forrest, but I also agree with Lewis's response to Forrest that without a measure over the class of other worlds, one cannot make this objection rigorous (Lewis, 1986, pp. 115–21). Thus, I have not pursued this objection here.

of affairs S that we normally take to be improbable. Consider, for example, a multiverse hypotheses M that attempts to explain the special initial conditions of our universe by hypothesizing that it is part of a vast array of universes all of which have the same laws L but in which every possible initial condition is realized. The standard inflationary-superstring scenario discussed in the next section contains such a multiverse as a subset. So do standard multiverse theories based on the existence of an infinite universe with widely varying initial conditions. Assuming that universes lack haecceities – which in this case implies that they are distinguished only by their initial conditions – and assuming the laws are deterministic, then M will entail the existence of our universe along with all of its properties. For example, M will entail DTx. Hence, the mere fact that M entails the existence of our universe and its life-permitting structure cannot be taken as undercutting the claim that it is improbable without at the same time undercutting claims such as that DTx is improbable. Of course, an advocate of M could always use the nondeducibility loophole discussed earlier to save the improbability of the actuality of these states of affairs, but that will open the door to the advocate of the fine-tuning argument's using the same loophole.[49] If this analysis is correct, it will spell trouble for those who claim that the multiverses discussed in contemporary cosmology – such as the inflationary multiverse – can undercut the improbability of the extraordinarily special initial conditions of our universe by claiming that every possible initial condition is realized in some universe or another.

6.3. The inflationary-superstring multiverse explained and criticized

As mentioned in Section 6.1, by far the most commonly advocated version of the restricted multiverse hypothesis is the "multiverse-generator" version that claims that our universe was generated by some physical process that produces an enormous number of universes with different initial conditions, values for the constants of nature, and even lower-level laws. Many scenarios have been proposed – such as the oscillating Big Bang model and Lee Smolin's claim that many universes are generated via black holes (Smolin 1997). Among these, the one based on inflationary cosmology conjoined with superstring theory is by far the most widely discussed and advocated, since this is the only one that goes beyond mere speculation. According to inflationary cosmology, our universe started from an exceedingly small region of space that underwent enormous expansion due to a hypothesized *inflaton* field that both caused the expansion and imparted a constant, very large energy density to space as it expanded. The expansion caused the temperature of space to decrease, causing one or more so-called "bubble universes" to form. As each bubble

49. If universes have haecceities, then M would not necessarily entail the existence of our universe but only one qualitatively identical with it. In that case, M would not necessarily entail DTx, but only that a die qualitatively identical to D came up on six 100 times in a row. Allowing for haecceities, however, means that one must consider the improbability of purely indexical LP facts about our universe, since the essential features of our universe no longer must include all of its qualitative properties, such as its initial conditions. In that case, the fine-tuning argument could be relocated to the indexical fact regarding the improbability of *our* universe's having life-permitting initial conditions, since M no longer entails that *our* universe U has the initial conditions it does. (The earlier argument was formulated on the assumption that the laws are deterministic; I believe that a similar argument also works if the laws are indeterministic, but I cannot pursue it here.)

universe is formed, the energy of the inflaton field is converted into a burst of "normal" mass-energy, thereby giving rise to a standard Big Bang expansion of the kind we see in our universe.

In *chaotic inflation* models – widely considered the most plausible – space expands so rapidly that it becomes a never-ending source of bubble universes. Thus, an enormous number of universes naturally arise from this scenario. In order to get the parameters of physics to vary from universe to universe, however, there must be a further physical mechanism/law to cause the variation. Currently, many argue that this mechanism/law is given by superstring theory or its proposed successor, M-Theory, which are widely considered the only currently feasible candidates for a truly fundamental physical theory. It should be stressed, however, that both inflationary cosmology and superstring/M-Theory are highly speculative. For example, Michio Kaku states in his recent textbook on superstring theory, "Not a shred of experimental evidence has been found to confirm . . . superstrings" (1999, p. 17). The same remains true today. The major attraction of superstring/M-Theory is its mathematical elegance and the fact that many physicists think that it is the only game in town that offers significant hope of providing a truly unified physical theory of gravitation with quantum mechanics (Greene 1999, p. 214).

6.3.1. Inflationary-superstring multiverse requires right laws

One major possible theistic response to the multiverse generator scenario, whether of the inflationary variety or some other type, is that the laws of the multiverse generator must be just right – fine-tuned – in order to produce life-sustaining universes. To give an analogy, even a mundane item such as a bread machine, which only produces loaves of bread instead of universes, must have the right structure, programs, and ingredients (flour, water, yeast, and gluten) to produce decent loaves of bread. Thus, it seems, invoking some sort of multiverse generator as an explanation of the fine-tuning reinstates the fine-tuning up one level, to the laws governing the multiverse generator. So, at most, it could explain the fine-tuning of the constants and initial conditions. (Even the latter will be problematic, however, as we shall see in the next two sections.)

As a test case, consider the inflationary type multiverse generator. In order for it to explain the fine-tuning of the constants, it must hypothesize one or more "mechanisms" or laws that will do the following five things: (i) cause the expansion of a small region of space into a very large region; (ii) generate the very large amount of mass-energy needed for that region to contain matter instead of merely empty space; (iii) convert the mass-energy of inflated space to the sort of mass-energy we find in our universe; and (iv) cause sufficient variations among the constants of physics to explain their fine-tuning.

Glossing over the details, in inflationary models, the first two conditions are met via two factors. The first factor is the postulated inflaton field that gives the vacuum (that is, empty space), a positive energy density. The second factor is the peculiar nature of Einstein's equation of General Relativity, which dictates that space expand at an enormous rate in the presence of a large near-homogenous positive energy density (see Section 2.3.3). Finally, because the inflaton field gives a constant positive energy density to empty space, as space expands the total vacuum energy within the space in question will increase enormously. This, in turn, generates the needed energy for the formation of matter in the universe. As one text in cosmology explains, "the vacuum acts as a reservoir of unlimited energy, which can supply as much as is required to inflate a given region to any required size at constant energy density" (Peacock 1999, p. 26).

So, to achieve (i)–(ii), we effectively have a sort of "conspiracy" between at least two different factors: the inflaton field that gives empty space a positive energy density, and Einstein's equation. Without either factor, there would neither be regions of space that inflate nor would those regions have the mass-energy necessary for a universe to exist. If, for example, the universe obeyed Newton's theory of gravity instead of Einstein's, the vacuum energy of the inflaton field would at best simply create a gravitational attraction causing space to contract, not to expand.

The conversion of the energy of the inflaton field to the normal mass-energy of our universe (condition (iii)) is achieved by Einstein's equivalence of mass and energy, $E = mc^2$, along with the assumption that there is a coupling between the inflaton field and the matter fields. Finally, the variation in the constants (and to some extent the laws) of nature is typically claimed to be achieved by combining inflationary cosmology with superstring/M-Theory, which purportedly allows for an enormous number (greater than 10^{500}) possible combinations of values for the constants of physics. The important point here is that the laws underlying the inflationary scenario must be just right in order to cause these variations in the constants of physics from one universe to another. If the underlying laws are those given by superstring/M-Theory, arguably there is enough variation; this is not the case, however, for the typical grand unified theories that have been recently studied, which allow for only a very limited number of variations of the parameters of physics, about a dozen or so in the case of the simplest model (Linde 1990, p. 33). As Joseph Polchinski notes in his textbook on superstring theory (1998, vol. II, pp. 372–3), there is no reason to expect a generic field to have an enormous number of stable local minima of energy, which would be required if there is to be a large number of variations in the constants of physics among universes in inflationary cosmology.

In addition to the four factors listed, the fundamental physical laws underlying a multiverse generator – whether of the inflationary type or some other – must be just right in order for it to produce life-permitting universes, instead of merely dead universes. Specifically, these fundamental laws must be such as to allow the conversion of the mass-energy into material forms that allow for the sort of stable complexity needed for complex intelligent life. For example, as elaborated in Section 2.2, without the Principle of Quantization, all electrons would be sucked into the atomic nuclei, and, hence atoms would be impossible; without the Pauli Exclusion Principle, electrons would occupy the lowest atomic orbit, and hence complex and varied atoms would be impossible; without a universally attractive force between all masses, such as gravity, matter would not be able to form sufficiently large material bodies (such as planets) for life to develop or for long-lived stable energy sources such as stars to exist.

Although some of the laws of physics can vary from universe to universe in superstring/M-Theory, these fundamental laws and principles underlie superstring/M-Theory and therefore cannot be explained as a multiverse selection effect. Further, since the variation among universes would consist of variation of the masses and types of particles, and the form of the forces between them, complex structures would almost certainly be atomlike and stable energy sources would almost certainly require aggregates of matter. Thus, the said fundamental laws seem necessary for there to be life in *any* of the many universes generated in this scenario, not merely in a universe with our specific types of particles and forces.

In sum, even if an inflationary-superstring multiverse generator exists, it must have just the right combination of laws and fields for the production of life-permitting universes: if one of the components were missing or different, such as Einstein's equation or the Pauli Exclusion Principle, it is unlikely that any life-permitting universes could be produced. Consequently, at most, this highly speculative scenario would explain the fine-tuning of the constants of physics, but at the cost of postulating additional fine-tuning of the laws of nature.

6.3.2. Low-entropy problems for inflationary cosmology

Inflationary cosmology runs into a major problem in explaining the low entropy of the universe. This is a critical problem, since unless it can do this, arguably much, if not all, of the motivation for inflationary cosmology vanishes. Further, this problem will cast severe doubt on the ability of an inflationary multiverse to explain the fine-tuning. The problem is that, applied to the universe as a whole, the second law of thermodynamics demands that the entropy of the universe always increase. Indeed, even if one has doubts about the applicability of the second law to the universe as a whole, inflation invokes a thermalization process, and thermalization is known to be a paradigmatic entropy-increasing process. As Oxford University physicist Roger Penrose states:

> Indeed, it is fundamentally misconceived to explain why the universe is special in *any* particular respect by appealing to a thermalization process. For, if the thermalization is actually doing anything (such as making temperatures in different regions more equal than they were before), then it represents a definite increasing of entropy. Thus, the universe would have had to be more special before the thermalization than after. This only serves to increase whatever difficulty we might have had previously in trying to come to terms with the initial extraordinarily special nature of the universe. . . . invoking arguments from thermalization, to address this particular problem [of the specialness of the universe], is worse than useless! (2004, p. 756)

Based on this sort of argument, it is now widely accepted that the preinflationary patch of space-time that inflated to form our universe must have had lower entropy than the universe right after inflation. For example, Andreas Albrecht, a defender of inflationary cosmology, admits that inflationary cosmology must hypothesize a special initial low entropy state: "For inflation, the *inflaton field* is the out-of-equilibrium degree of freedom that drives other subsystems. The inflaton starts in a fairly homogeneous potential-dominated state which is certainly not a high-entropy state for that field . . ." (2004, p. 382). Elsewhere, he says the preinflation patch must have been in a "very special state" (2004, p. 380).

6.3.3. Albrecht's "dominant channel" response

So, how does inflation explain the special initial conditions of the Big Bang, which is the primary aim of the theory? According to Albrecht, it explains the initial conditions by a two-stage process, via the "chaotic inflation" models mentioned in Section 6.3. First, as Albrecht explains, "One typically imagines some sort of chaotic primordial state, where the inflaton field is more or less randomly tossed about, until by sheer chance it winds up in a very rare fluctuation that produces a potential-dominated state . . ." (Albrecht 2004, p. 384). Potential-dominated states are those in which the potential energy of the inflaton field is enormous compared to the rate of change of the inflaton field with respect to time and space. That is, in order for inflation to occur, the inflaton field must be almost uniform both spatially and temporally relative to the total energy density of the field (Peacock 1999, p. 329). Although macroscopic uniformity of matter is typically a state of very high entropy (such as perfume spread throughout a room), it is generally accepted that in the case of the gravitational field and the inflaton field, greater uniformity entails lower entropy. This is said to explain why the universe becomes more and more inhomogeneous as it expands (with matter clustering into galaxies and stars forming), and yet at the same time its entropy increases. Entropy increases because the gravitational field becomes less uniform. Since the gravitational field would play a significant role in the space-time of the early universe, a near uniform inflaton field would correspond to extremely low entropy.

Now a general requirement for inflation is that the inflaton field be nearly uniform, in the potential-dominated sense defined earlier, over some very small patch. Although these states will be extremely rare, given a large enough initial inflaton field, or enough time, they are likely eventually to occur in some small patch of space simply as a result of thermal fluctuations. Once they occur, inflation sets in, enormously expanding the patch. Eventually, because of the postulated nature of the inflaton field, in one or more regions of this expanded space, the field decays, resulting in reheating that produces a bubble universe with ordinary matter. So, in effect, because inflation can only occur in highly uniform states of the inflaton field, any universe produced from an inflated region will have initially low entropy.

Accordingly, Albrecht proposes that inflation explains the low entropy of our universe by a two-stage process: (i) a low-entropy patch occurs as a result of a statistical fluctuation, and then (ii) that patch inflates into our universe. As John Barrow and Frank Tipler pointed out over 20 years ago (1986, p. 437), however, if the right special initial conditions must be stumbled upon by a statistical fluctuation, why not simply hypothesize a very large, or infinite, material field that undergoes a random fluctuation that produces a universe relevantly like ours? Why invoke the additional mechanism of inflation?

The answer requires looking at the standard objection to "random fluctuation models." The objection is that universes being produced by such a fluctuation (without inflation) would almost certainly lead to small islands of observers surrounded by chaos, not one with a low degree of entropy throughout. Even more ominously, a random observer most likely would be a so-called Boltzmann brain (BB). A BB is a small region of mass-energy with the same structure as our brains (including the same sort of apparent memory and sensory experiences), but with the surrounding regions of space and time in a chaotic, high-entropy state. Although the experiences of such brains would be highly ordered for a brief time, they would not in any way correspond to reality, and any sort of inductive reasoning would fail.

The BB concept was originally articulated as part of an objection raised against the proposed anthropic-selection-effect explanation of the low initial entropy offered by Ludwig Boltzmann, one of the principal founders of statistical mechanics. Boltzmann attempted to explain the relatively low entropy of the universe by claiming that it was the result a fluctuation from the normal "chaotic," equilibrium state, and that a fluctuation with a high degree of order was necessary for the existence of observers. As theoretical physicist Paul Davies and many others have pointed out in response to Boltzmann's anthropic explanation, a fluctuation "the size of the solar system would be sufficient to ensure the existence of life on Earth, and such a fluctuation is *far* more probable than one of cosmic proportions" (Davies 1974, p. 103). Indeed, fluctuations of even smaller dimensions – ones in which matter has the same organization as the brain with all its apparent memories and sense experiences but in which the surrounding space-time was chaos – would be even more likely. Consequently, insofar as a random fluctuation world contained observers, any randomly selected observer would almost certainly be a BB.

To intuitively see why Davies's statement is correct, consider an analogy of a very large scrabble board. If we were to shake the scrabble board at random, we would be much more likely to get an ordered, meaningful arrangement of letters in one small region, with the arrangement on the rest of the board essentially chaotic, than for all the letters on the entire board to form meaningful patterns. Or, as another analogy, consider a hundred coins lined up in a row, which are then shaken at random. Define a local island of order to be any consecutive sequence of five coins which all are on the same side – that is, either all heads or all tails. It is much more likely for the sequence of a hundred coin tosses to contain one or more subsequences of five consecutive heads or tails than for it to be all heads or all tails. Indeed, it is likely that such a sequence of coins will have at least one such island of five consecutive heads or tails; the probability of the coins coming up all heads or all tails, however, is around one in 10^{30}, or one in a thousand, billion, billion, billion.

The same argument applies to the mass-energy configurations of our visible universe, with the argument being grounded in probability calculations based on the standard probability measure of statistical mechanics over phase space. Roger Penrose's calculations show that among all possible configurations, it is enormously more likely (by a factor of around 1 in 10^x, where $x = 10^{123}$) for local islands of low entropy to form than the whole visible universe to be in a low-entropy state (see e.g. Penrose 2004, pp. 762–5). Indeed, if we consider the set of all configurations of mass-energy that would result in an observer – for example, an organized structure with the same relevant order as our brain – the subset of such configurations that are dominated by BB observers would be far, far larger than those configurations that are dominated by non-BB observers.

Some people attempt to draw from these calculations the conclusion that if the random fluctuation model is correct, we should then expect ourselves to be BBs. This assumption, however, is difficult to justify. We can, however, derive the more limited conclusion that under the random fluctuation model it is epistemically very likely that we are BBs conditioned on only our purely subjective experiences: that is, $P(BB|k' \,\&\, RF) \sim 1$, where BB represents the hypothesis that "I am a BB," RF the claim that the random fluctuation model is correct, and k′ includes all of one's own "purely subjective" experiences but no claim that these experiences correspond to reality.

Many have argued, however, that we have noninferential knowledge of the existence of the external world – that is, knowledge of the external world that cannot be deduced from k′. If this is right, then $P(BB|k \,\&\, RF) = 0$, where $k^* =$ there is an external world that generally corresponds to our subjective experiences, and $k = k' \,\&\, k^*$ is our relevantly complete background information. This is the reason we cannot derive the skeptical conclusion that if the random fluctuation model is true, we should expect ourselves to be BBs. However, since $P(\sim BB \,\&\, k^*|RF \,\&\, k') \ll 1$, the elaborated RF hypothesis, $k \,\&\, RF = \sim BB \,\&\, k' \,\&\, k^* \,\&\, RF$, suffers from a severe probabilistic tension that the elaborated ~RF hypothesis, $k \,\&\, \sim RF = \sim BB \,\&\, k' \,\&\, k^* \,\&\, \sim RF$, does not. (Here, ~BB is the claim that we are not BBs, and ~RF is the denial of the RF model.) This probabilistic tension gives us strong reasons to accept ~RF over RF, given that that we are not BBs. Or, given that ~RF is not *ad hoc* in the sense defined in section 1.3, the restricted version of the Likelihood Principle implies that

~BB & k* strongly confirms ~RF over RF, since P(~BB & k*|RF & k′) $\ll$ 1 and ~P(~BB & k*|~RF & k′) $\ll$ 1.[50]

A major question for a chaotic inflationary multiverse model is whether it can circumvent the BB problem that plagues the random fluctuation model. If not, such a model will encounter the same disconfirmation as RF, thus giving us strong reasons to reject it. According to Albrecht, the inflationary model can avoid the BB problem, and this is its key advantage. Says Albrecht:

> Inflation is best thought of as the "dominant channel" from random chaos into a big bang-like state. *The exponentially large volume of the Big Bang-like regions produced via inflation appear to completely swamp any other regions that might have fluctuated into a Big Bang-like state via some other route.* So, if you went looking around in the universe looking for a region like the one we see, it would be exponentially more likely to have arrived at that state via inflation, than some other way, and is thus strongly predicted to have the whole package of inflationary predictions. (Albrecht 2004, p. 385; italics added)[51]

The idea here is that inflation takes small, low-entropy regions and expands them into enormously large regions with enough order so that they will be dominated by non-BB observers (if they have observers). The assumption is that the regions that undergo inflation are so small that they are much more likely to occur than regions that generate observers by random fluctuations; further, because of inflation, these initially small regions become so large that they dominate over those regions that produce observers by means of random fluctuations. Albrecht admits, however, that his argument that inflation would be the dominant channel "rests on very heuristic arguments" and that "the program of putting this sort of argument on firmer foundations is in its infancy" (2004, p. 396).

Several articles have been written in recent years arguing that inflation will generate universes in which BBs enormously dominate among observers in the far future (Bousso & Freivogel 2006; Banks 2007).[52] These arguments, however, might only present a problem if one adopts a block universe view, according to which future events have the same ontological status as present and past events. Although advocates of inflation typically assume such a view, they need not. If one adopts a metaphysical view in which the future is not yet real, these arguments will not themselves show that inflation leads to a present dominance of BB universes. Further, as cosmologist Don Page (2006) has pointed out, the same dominance of BBs occurs for long-lived single universes; further, the evidence at present strongly suggests that our universe will continue existing for an enormously long time, if not forever, if there is no supernatural intervention. In any case, I shall next present a powerful reason

50. The claim that P(~BB & k*|RF & k′) $\ll$ 1 assumes that one can separate out a "purely subjective" element of experience (corresponding to k′) from other aspects of experience that essentially involve reference to the external world. Some deny this assumption, although it seems very plausible to me. I also should note that the aforementioned argument provides a more rigorous way of proceeding than invoking the so-called "typicality" assumption – that we are in some ill-defined sense "typical observers" – so often invoked in discussions of the BB problem.

51. See Albrecht (2004) for a more detailed presentation of this argument, especially pages 385–87 and 390.

52. I would like to thank James Sinclair for pointing out some of these articles to me. For a recent review of the literature, see Banks (2007, ref. 4).

for thinking that Albrecht's argument is flawed and that without assuming highly special initial conditions, inflationary cosmology leads to a dominance of BBs for *any* period of time in which observers exist. Since there are many versions of inflationary cosmology, my argument will be very general.

6.3.4. A BB objection to the inflationary multiverse

There is a simple argument that if the BB problem exists for the random fluctuation multiverse, then the same problem exists for the inflationary multiverse. Define a *megaverse* as some very large finite, or even infinite, region of space-time of a universe or multiverse that has some configuration of mass-energy in it.[53] The BB problem arises for a random fluctuation multiverse because, when the standard measure *M* of statistical mechanics is applied to the phase space of an arbitrary megaverse, the measure of configurations dominated by non-BB observers is much, much smaller than that of those configurations dominated by BB observers. Further, if this is true for the entire megaverse, then it will have to be true for any arbitrarily chosen spacelike hypersurface, hp, of constant time t of the megaverse. Thus, if we let $M_t(BB)$ designate the measure of volume, $V_t(BB)$, of the phase space of hp corresponding to those configurations dominated by BB observers, and $M_t(\sim BB)$ designate the volume, $V_t(\sim BB)$, of hp corresponding to configurations dominated by non-BB observers, then $M_t(\sim BB)/M_t(BB) \ll 1$.[54] That is, the measure for the possible mass-energy-momentum configurations of hp that are non-BB dominated will be much, much smaller than the measure for those configurations that are BB dominated. Assuming that the laws of physics are deterministic and time-reversal invariant, then the measure is time-invariant, as explained in Section 2.4. If we consider the mass-energy-momentum configurations of hp as evolving with time, this means that for any volume of phase space $V(t_0)$ of measure $M_{V(t_0)}$ at time t_0, $V(t_0)$ will evolve into a volume $V(t)$ of the same measure at time t: that is, $M_{V(t)} = M_{V(t_0)}$.

Now, consider the initial conditions of the megaverse defined on some spacelike hypersurface of constant time t_0. Let $V_{t_0}(BB)$ and $V_{t_0}(\sim BB)$ represent the volume of phase space of that hypersurface that evolves into configurations dominated by BB observers and by non-BB observers, respectively, for some later hypersurface at time t. Since the statistical mechanics measure m is time-invariant, the ratio of the measure of $V_{t_0}(\sim BB)$ to $V_{t_0}(BB)$, that is, $M_{t_0}(\sim BB)/M_{t_0}(BB)$, will remain the same. Consequently, $M_{t_0}(\sim BB)/M_{t_0}(BB) = M_t(\sim BB)/M_t(BB) \ll 1$. This means that the measure of initial states that give rise to a universe dominated by non-BB observers at some arbitrarily chosen later time t is much, much smaller than the measure of initial states that give rise to a universe dominated by BB observers at t. Consequently, unless the initial state of the megaverse is in a very special low-probability state – that corresponding to volume $V_{t_0}(\sim BB)$ – it will give rise to a universe dominated by BBs. This is true for any megaverse in which the laws of physics are deterministic and time-reversal invariant. Inflationary cosmology denies neither of these assumptions. Further, even

53. I use the idea of a megaverse to avoid problems arising from defining a measure if the multiverse is infinite. If the multiverse is infinite, we could avoid such potential problems by making our megaverse finite but large enough to include many observers.

54. A universe is dominated by non-BB observers if and only if it contains at least one observer, and in some well-defined sense there is a greater proportion of non-BB observers than BB observers.

though the laws of physics are not strictly speaking time-reversal invariant – since time-reversal symmetry is broken in weak interactions, notably the decay of neutral kaons – the argument offered by Albrecht and others that was explicated in Section 6.3.3 does not, in any way, exploit this lack of invariance, nor does it exploit any sort of quantum indeterminacy. Thus, without assuming highly special initial conditions, inflationary cosmology cannot do better with regard to the BB problem than the random fluctuation multiverse.

To illustrate this argument, consider the following analogy. Let a highly ordered, low-entropy non-BB-dominated megaverse of finite volume containing observers be represented as a black-and-white TV screen with rows and rows of O's throughout, and let a megaverse dominated by BBs be represented by occasional O's with large patches of "snow" – that is, "random" configurations of black-and-white pixels. We shall call the former arrangement the ordered, non-BB-pixel arrangement, and the latter the BB-pixel arrangement. For simplicity, suppose there are only a finite number of pixels on the TV screen. In that case, the number of ordered non-BB-pixel arrangements would be very small compared with BB-pixel arrangements. Further, suppose the image on the TV screen is being generated by some small magnetic patch on a videocassette recorder (VCR) tape that the VCR head is reading. Finally, suppose that there is a one-to-one correspondence between arrangements of magnetic particles on the patch and the possible configurations of black-and-white pixels on the screen.

Because of the one-to-one correspondence, the ratio of possible configurations of magnetic particles on the patch of tape that give rise to non-BB-pixel arrangements to those that give rise to BB arrangements will be the same as the ratio of non-BB-pixel arrangements to BB-pixel arrangements on the TV screen. Thus, if the latter ratio is enormously small, so will the former ratio. This is analogous to what happens in the inflationary megaverse: because the laws of physics are deterministic and time-reversal invariant, every microstate $m(t_0)$ at time t_0 evolves into one and only one microstate, $m(t)$, at time t, and, hence, they can be put into a one-to-one correspondence. Consequently, just as the ratios of the number of non-BB-pixel configurations to the BB-pixel configurations is preserved from VCR patch to TV screen, the ratio of the measure of initial configurations that lead to non-BB-dominant universes to the measure of those that lead to BB-dominant universes is the same as the corresponding ratio at a later time t.[55]

55. The fundamental error in Albrecht's reasoning can be illustrated by another analogy. Consider a balloon that is being unevenly inflated. Suppose some patches of its two-dimensional surface are massively blown up – say by a trillionfold in each of its two dimensions (e.g. one-trillionth of a meter becomes a meter). This corresponds to the space out of which bubble universes form, some parts of which are inflated and other parts of which are not. Now, suppose one of the blown-up patches is one square meter in volume and is completely covered by adjacent black Os that are one centimeter in diameter, with the space in between simply consisting of random mix of black-and-white dots. The *scale of the order* on this patch is one centimeter; at a level of less than one centimeter, there is a random mix of black-and-white dots. The crucial thing to note, however, is that scale of order of the pre-blown-up patch will be much, much smaller: one-trillionth of a centimeter.

Now it is true that for any two patches, larger patches of the same order and scale of order will be much less likely to occur at random than small patches with the same order and scale – for example, a patch covered with adjacent Os of 1 cm in diameter that has an area of one square meter is much more likely to occur at random than a patch covered with the same pattern of Os that has an area of a thousand square meters. This kind of consideration misleads Albrecht into thinking that very small patches of space-time that inflate into large observer filled, non-BB universes are vastly more likely to occur than large patches of space-time that form

Some might try to dispute one or more of the assumptions of this argument. The most vulnerable assumptions are the problems of nonarbitrarily dealing with the possible infinities that might arise when one attempts to define a measure for the entire megaverse, along with the additional problem of making rigorous the claim that in the entire phase space, the measure of non-BB-dominated hypersurfaces is much, much less than that of BB-dominated hypersurfaces. These problems, however, are as much a problem for making Albrecht's argument rigorous. The whole point of Albrecht's argument is that inflation does better with regard to BBs than the random fluctuation multiverse. In order for this claim to be true, there must be some "correct" measure *M* for the possible mass-energy states of the multiverse (or at least for arbitrarily chosen very large finite subsets of it) such that non-BB-observer-dominated states have a much, much smaller measure than those of BB-observer-dominated states for the random fluctuation model.

In response, perhaps Albrecht could appeal to some notion of a "generic" initial state that is not dependent on the existence of a measure over phase space. Such an appeal, however, will immediately run afoul an objection Penrose has raised. Consider an enormously large universe that eventually collapses back on itself and assume that all the special laws that are required by inflation hold in that universe. (We could even have an infinite universe with a negative cosmological constant to ensure collapse.) Suppose that this universe had many domains, some of which are highly irregular. In fact, we can suppose that it is chock full of BBs. As Penrose points out, the collapse of such a universe will result in "a generic *space-time singularity,* as we can reasonably infer from precise mathematical theorems" (2004, p. 756). Assuming that the laws of physics (including those of inflation) are time-symmetric (as is typically assumed in these contexts), if we now reverse the direction of time in our model, we shall "obtain an evolution which starts from a general-looking singularity and then becomes whatever irregular type of universe we may care to choose" (2004, p. 757). Since the laws governing inflation will hold in this time-reversed situation, it follows that one cannot guarantee that a uniform or non-BB-dominant universe will arise from generic initial conditions. Thus, inflationary cosmology can explain such a universe only by effectively presupposing those subsets of generic initial conditions that will lead this type of universe. As Penrose notes, "The point is that whether or not we actually have inflation, the physical possibility of an inflationary period is of no use whatever in attempts to ensure that evolution from a generic singularity will lead to a uniform (or spatially flat) universe" (2004, p. 757).

a non-BB-observer-filled universe via a thermal fluctuation. Consequently, Albrecht is misled into thinking that inflation can help overcome the BB problem confronting the RF model by increasing the relative proportion of non-BB observers. The problem for Albrecht's reasoning is that in order to produce a non-BB observer-dominant universe, the order of the patch that inflates would have to be at a vastly smaller scale – for example, inversely proportional to the factor by which the patch inflated– and hence contain a vastly higher degree of order per unit of volume than a corresponding non-BB-observer patch of the size of our universe that did not inflate. ~~This~~ decrease in likelihood resulting from the higher degree of order compensates for the increase in probability resulting from the size of the patch, as can be seen by our more rigorous argument offered earlier based on the time-invariance of the standard measure. In terms of our balloon analogy, a square patch with sides one-trillionth of a meter in length filled with adjacent Os one-trillionth of a centimeter in diameter is no more likely to occur at random than a square patch with sides of 1 m in length filled with Os that are 1 cm in diameter.

6.3.5. Conclusion

The aforementioned arguments do not show that inflationary cosmology is wrong or even that scientists are unjustified in accepting it. What they do show is that the inflationary multiverse offers no help in eliminating either the fine-tuning of the laws of nature or the special low-entropic initial conditions of the Big Bang. With regard to the special low-entropic initial conditions, it can explain the special conditions of the Big Bang only by hypothesizing some other, even more special, set of initial conditions. Although a chaotic inflationary model might lead one to expect a universe like ours, unless highly special initial conditions are assumed across the entire multiverse, it leads to a multiverse dominated by BBs for ~~all~~ later times and thus does no better than a random fluctuation model. It also runs into the generic problems faced by multiverse hypotheses discussed at the end of Section 6.2. If we find the existence of a BB-dominated multiverse unacceptable, it follows that an inflationary-superstring multiverse at best eliminates only the need to explain the life-permitting values of the constants of physics (and perhaps other nonentropic types of special initial conditions). Because of the highly speculative extra laws and conditions required to make an inflationary multiverse work, one could not be blamed if one judged that such purported explanatory ability were far too costly.

7. Miscellaneous Objections

7.1. The "who designed God?" objection

Perhaps the most common objection that atheists raise to the argument from design is that postulating the existence of God does not solve the problem of design but merely transfers it up one level to the question, "Who or what designed God?" The eighteenth-century philosopher David Hume hinted at this objection:

> For aught we can know *a priori*, matter may contain the source or spring of order originally within itself, as well as mind does; and there is no more difficulty conceiving that the several elements, from an internal unknown cause, may fall into the most exquisite arrangement, than to conceive that their ideas, in the great universal mind, from a like unknown cause, fall into that arrangement. (Hume 1980, pp. 17–8)

A host of atheist philosophers and thinkers, such as J. L. Mackie (1982, p. 144), Graham Oppy (2006, pp. 183–4), J. J. C. Smart (1985, pp. 275–6), Richard Dawkins (1986, p. 316), and Colin McGinn (1999, p. 86) have also repeated this objection. For example, J. J. C. Smart claims that:

> If we postulate God in addition to the created universe we increase the complexity of our hypothesis. We have all the complexity of the universe itself, and we have in addition the at least equal complexity of God. (The designer of an artifact must be at least as complex as the designed artifact). (1985, pp. 275–6)

As an objection to our version of fine-tuning argument, it is flawed on several grounds. I have addressed this objection in detail elsewhere (Collins 2005a). Here I shall present a brief response. To begin, this objection would arise only if either T were constructed *solely* to *explain* the fine-tuning, without any independent motivation for believing it, or one considered these other motivations as data and then justified T by claiming that it is the best explanation of all the data. Our main argument, however, is not that T is the best explanation of all the data, but only that given the fine-tuning evidence, LPU strongly confirms T over NSU.

Further, we have substantial reasons for *not* treating the other motivations for T like data, which we then combine with the fine-tuning evidence to infer to the best explanation. To illustrate, let me focus on one such motivation. Many theists have claimed that for most people at least, belief in God is grounded in a fundamental intuition regarding the existence of God, an intuition relevantly similar to moral intuitions or the intuitions regarding epistemic norms. If this is right, then, as Keith Ward and others have noted, treating the existence of God like a scientific hypothesis that needs to be justified by some form of inference to the best explanation is "like trying to justify moral belief by reference to the findings of the natural sciences" (1987, p. 178). On this view, faith can be seen as itself "a response to one who claims my loyalty by showing the true nature of my present mode of being and the way of salvation" (Ward 1987, p. 178). It is "a basic and distinctive mode of human thought and activity" (Ward 1987, p. 180). Thus, in analogy to our ethical intuitions, faith should be considered a mode of knowing, not just a mere leap of belief under insufficient evidence. Plantinga (2000) has provided one way of carefully developing this view and shows it has been commonplace in the Christian tradition – for example, Thomas Aquinas and John Calvin (Plantinga 2000, chap. 6). From this point of view, the religious mode of knowing or justification involved in faith, therefore, should *not* be treated as providing data for an inference to the best explanation but rather as analogous to our ethical intuitions, or even our intuitions regarding epistemic virtues – for example, that, everything else being equal, simpler theories are more likely to be true or empirically adequate than complex theories. Clearly, one cannot ground our belief in these epistemic virtues in an inference to the best explanation, since all such inferences presuppose the virtues. Finally, William Alston (1993) and others have made similar claims with regard to our knowledge of God based on religious experience, claiming it is relevantly analogous to our knowledge of the material world, which they claim is not justified by appeal to an inference to the best explanation.

If we do not treat these other motivations for T as part of a body of data for which we employ the strategy of inference to the best explanation, then the "who designed God?" objection largely evaporates. The existence of God is not a hypothesis that is being offered as the best explanation of the structure of the universe, and hence it is not relevant whether or not God is an explanatorily better (e.g. simpler) terminus for ultimate explanation than the universe itself. Nonetheless, via the restricted version of the Likelihood Principle (Section 1.3), the various features of the universe can be seen as providing *confirming* evidence for the existence of God. One advantage of this way of viewing the situation is that it largely reconciles the views of those who stress a need for faith in coming to believe in God and those who stress reason. They each play a complementary role.

To illustrate this point, consider the following analogy. Suppose that in the year 2050 extraterrestrials visit Earth, and we find that they share the same fundamental ethical beliefs as we do – for example, that it is wrong to torture others for no compelling ethical reason. Further, suppose that we were able to show that it is very epistemically unlikely that such an agreement would occur under ethical antirealism – for example, because we have good reason to believe both that unguided naturalistic evolution would not produce these beliefs and that ethical antirealism is not compatible with viable, alternative explanations of human beings based on design (such as T). Finally, suppose we could show that it is not unlikely for this agreement to occur under ethical realism.[56] The discovery that these aliens shared the same ethical beliefs as we do would therefore confirm ethical realism, even though we would not believe ethical realism because it provided the best explanation of some set of phenomena. In fact, I believe it would decisively tip the balance in favor of ethical realism. I suggest that the evidence of fine-tuning does the same for T.

Apart from rejecting the claim that the justification for the existence of God is based on some sort of inference to the best explanation, however, one can also object to the atheist's key assumption, articulated by J. J. C. Smart in the aforementioned quotation, that the "designer of an artifact must be at least as complex as the artifact itself." This assumption is not even clearly true in the human case, since it is at least conceivable that one could produce a computer that is more complicated than oneself, which is a common theme of science fiction. In the case of God, however, we have even less reason to believe it. If the theist were hypothesizing an anthropomorphic God, with a brain and a body, then this objection would be much stronger: one would then be tempted to ask, is that not God's brain and body as much in need of an explanation as the universe itself? Thus, this objection might seem to have significant bite against such a conception of God. Within traditional theism, however, God has always been claimed to lack any sort of significant internal complexity. In fact, most of the Western medieval tradition claimed that God was absolutely simple in every way – God did not even have complexity with regard to God's properties. Aquinas, for instance, claimed that all of God's properties (such as God's omnipotence and perfect goodness) were absolutely identical; these were, in turn, identical with God's essence and existence. Although I do not think that this view of God as being absolutely simple is coherent, the point here is that the "who designed God?" objection begs the question against traditional theism, by assuming a type of God which traditional theists would all disavow. Even the heirs to traditional Western theism who deny absolute divine simplicity, such as Richard Swinburne (2004), claim that God's overall being is extraordinarily simple. Thus, what these atheists really need to show is that the God of all varieties of traditional theism is logically incoherent insofar as those versions of theism hold on to some form of divine simplicity. This, however, is a very different objection – and a much harder task – than simply raising the "who designed God?" objection and then claiming that one has eliminated the theistic explanation in a single stroke.

7.2. The more fundamental law objection

One criticism of the fine-tuning argument is that, as far as we know, there could be a more fundamental law that entails both the current laws of physics and the values of the constants of physics. Thus, given such a law, it is not improbable that the laws and constants of physics fall within the life-permitting range. Besides being entirely speculative, three problems confront such an objection. First, although many physicists had hoped that superstring theory would entail all the current laws and constants of physics, that hope has

56. For example, we might argue that it is not unlikely under ethical realism because ethical realism entails some form of ethical Platonism and because Platonism requires that the mind has some sort of direct access to Platonic truths.

almost completely faded as string theorists have come to recognize that superstring theory (and its proposed successor, M-Theory) has many, many solutions, estimated at 10^{500} or more. Consequently, the prospects of discovering such a fundamental law are much dimmer than they once were. Second, such a fundamental law would not explain the fine-tuning of the initial conditions of the universe. Finally, hypothesizing such a law merely moves the epistemic improbability of the fine-tuning of the laws and constants up one level, to that of the postulated fundamental law itself. Even if such a law existed, it would still be a huge coincidence that the fundamental law implied just those lower-level laws and values of the constants of physics that are life-permitting, instead of some other laws or values. As astrophysicists Bernard Carr and Martin Rees note "even if all apparently anthropic coincidences could be explained [in terms of some fundamental law], it would still be remarkable that the relationships dictated by physical theory happened also to be those propitious for life" (1979, p. 612). It is very unlikely, therefore, that the fine-tuning of the universe would lose its significance even if such a law were verified.

To illustrate the last response, consider the following analogy. Suppose that superdeterminism is true: that is, everything about the universe, including its initial conditions, is determined by some set of laws, although we do not know the details of those laws. Now consider a flip of a coin and let L_h and L_t denote the claims that the laws are such as to determine the coin to come up heads and tails, respectively. We would have equal reason to believe that L_h as that L_t. Hence, since L_h entails that the coin will come up heads, and L_t that the coin will come up tails, the epistemic probability of heads remains 50 percent, and likewise for tails. This would be true even though each of their physical probabilities would be one or zero. The fact that the laws of nature determine the initial conditions, instead of the initial conditions' not being determined by any law, has no influence on the epistemic probability. This can be seen also by the fact that when Laplacian determinism was thought to be true, everyone nonetheless gave a fair coin a 50 percent chance of coming up heads.

A similar sort of response can be given to the claim that fine-tuning is not improbable because it might be *logically necessary* for the constants of physics to have life-permitting values. That is, according to this claim, the constants of physics must have life-permitting values in the same way 2 + 2 must equal 4, or the interior angles of a triangle must add up to 180 degrees in Euclidian geometry. Like the "more fundamental law" proposal mentioned, however, this postulate simply transfers the epistemic improbability up one level: of all the laws and constants of physics that conceivably could have been logically necessary, it seems highly *epistemically* improbable that it would be those that are life-permitting, at least apart from some sort of *Axiarchic* Principle discussed in Section 8.[57]

7.3. Other life-permitting laws objection

According to what I call the "other life-permitting laws objection," there could be other life-permitting sets of laws that we know nothing about. This objection is directly answered by the way in which I have formulated the fine-tuning argument. As I formulated it, the fine-tuning argument does not assume that ours is the only possible set of life-permitting

57. As explained in Section 3.2, necessarily true propositions can still have an epistemic probability of less than one.

laws. Rather, it only assumes that the region of life-permitting laws (or constants or initial conditions) is very small compared with the region for which we can determine whether the laws, constants, or initial conditions are life-permitting – that is, what I called the EI region (see Section 4.5). In the case of the constants of physics, it assumed only that given our current laws of nature, the life-permitting range for the values of the constants (such as gravity) is small compared to the *surrounding* EI range for which we can determine whether or not a value is life-permitting.

7.4. Other forms of life objection

As raised against the fine-tuning argument based on the constants of physics, the "other forms of life objection" claims that as far as we know, other forms of non-carbon-based life could exist even if the constants of physics fell outside the purported life-permitting region. So, it is claimed, the fine-tuning argument ends up presupposing that all forms of embodied, conscious life must be based on carbon (e.g. Stenger 2004, pp. 177–8). Besides the extreme difficulty of conceiving of how non-carbon-based material systems could achieve the sort of self-reproducing material complexity needed to support embodied moral agents, another problem with this objection is that many cases of fine-tuning do not presuppose that all life must be carbon based. Consider, for instance, the cosmological constant. If the cosmological constant were much larger than it is, matter would disperse so rapidly that no stars could exist. Without stars, however, there would be no stable energy sources for complex material systems of any sort to evolve. So, all the fine-tuning argument presupposes in this case is that the evolution of embodied moral agents in our universe require some stable energy source. This is certainly a very reasonable assumption.

7.5. Weak Anthropic Principle objection

According to the weak version of so-called *Anthropic Principle*, if the laws of nature were not fine-tuned, we should not be here to comment on the fact. Some have argued, therefore, that LPU is not really *improbable or surprising* at all under NSU, but simply follows from the fact that we exist. In response, we simply restate the argument in terms of our existence: our existence as embodied moral agents is extremely unlikely under NSU, but not improbable under T, and therefore our existence confirms T over NSU. As explained in Section 4.3, this requires that we treat LPU and our existence as "old evidence," which we subtract from our background information. This allows us to obtain an appropriate background information k′ that does not entail LPU. The other approach was to use the method of probabilistic tension, which avoided the issue entirely (see Sections 1.4, 4.3, and 4.4).

The methods used in Section 4 deal with this problem of old evidence, and our arguments in Section 3.2 for the existence of conditional epistemic probabilities for P(A|B & k′) for some cases in which our own existence entails A, provide the formal underpinnings in support of the intuitions underlying the "firing-squad" analogy offered by John Leslie (1988, p. 304) and others in response to this objection. As Leslie points out, if 50 sharpshooters all miss me, the response "if they had not missed me I would not be here to consider the fact" is inadequate. Instead, I would naturally conclude that there was some reason why they all missed, such as that they never really intended to kill me. Why would I conclude this? Because, conditioned on background information k′ that does not include my continued existence – such as the background information of a third-party observer watching the execution – my continued existence would be very improbable under the hypothesis that they intended to kill me, but not improbable under the hypothesis that they did not intend to kill me.[58]

8. Conclusion: Putting the Argument in Perspective

As I developed in Sections 1.3 and 1.4, the fine-tuning argument concludes that, given the evidence of the fine-tuning of the cosmos, LPU significantly confirms T over NSU. In fact, as shown in Section 5.2, a good case can be made that LPU *conjoined* with the existence of evil significantly confirms T over NSU. This does not itself show that T is true, or even likely to be true; or even that one is justified in believing in T. Despite this, I claimed that such confirmation is highly significant – as significant as the confirmation that would be received for moral realism if we discovered that extraterrestrials held the same fundamental moral beliefs that we do and that such an occurrence was very improbable under moral antirealism (see Section 7.1). This confirmation would not itself show that moral realism is true, or even justified. Nonetheless, when combined with other reasons we have for endorsing moral realism (e.g. those based on moral intuitions), arguably it tips the balance in its favor. Analogous things, I believe, could be said for T.

I also considered the challenge raised by the two most widely advocated versions of the multiverse hypothesis – what I called the unrestricted multiverse hypothesis, advocated by Lewis and Tegmark, according to which all possible universes exist, and the *restricted* multiverse hypothesis arising out of inflationary cosmology. I argued that neither of these is able adequately to explain away the fine-tuning or undercut the fine-tuning argument.

Finally, one might wonder whether there are other viable alternative explanations of LPU to that offered by T, NSU, or the multiverse hypothesis. One such possibility is various nontheistic design hypotheses – either nontheistic supernatural beings or aliens in some meta-universe who can create bubble universes. The postulated designer, D, could

58. Sober rejects this sharpshooter analogy (2005, pp. 137–40). He admits, however, that for a bystander, the sharpshooters' missing (evidence E) would strongly support the "fake-execution" hypothesis (FE) that the captors never really intended to shoot the prisoner. He then goes on to claim that for the prisoner, E does not support FE, claiming that "the bystander and prisoner are in different epistemic situations, even though their observation reports differ by a mere pronoun" (p. 138). To see the problem with Sober's claim, suppose that: (i) the prisoner and bystander had exactly the same prior probabilities for the FE hypothesis (say, 0.01); (ii) they had relevantly the same cognitive faculties; and (iii) they both had all the same information that could be expressible in sentences, except the difference in the pronouns each would use. Finally, suppose they had to make a practical decision whether to risk their lives with a dangerous escape attempt or to bet that the captors did not intend to kill them. How should the bystander advise the prisoner? Attempt to flee, because $P(FE) < 0.5$ from the prisoner's perspective? Do not attempt to flee because $P(FE) \sim 1$ for the bystander? And, if they wanted to flee together, whose perspective do they go with? Surely, the bystander should not go with the prisoner's perspective, since the bystander's perspective involves nothing suspicious – there is no observational selection effect for the bystander. Furthermore, it seems clear that the prisoner cannot support his probability claim over that of the bystander's by appeal to special insight based on experiencing the attempted execution, since both would agree that this does not give special insight. (This is one way this case differs from religious and other kinds of fundamental disagreement.) Thus, if there is any course of action which is rational regarding fleeing together, it is that given by the bystander's perspective. So, contrary to Sober, there cannot be two radically different rational degrees of belief in FE.

not be a merely "generic" designer but must be hypothesized to have some motivation to create a life-permitting universe; otherwise P(LPU|D & k′) = P(LPU|NSU & k′), as explained in Section 5.2. Unless these non-generic hypotheses were advocated prior to the fine-tuning evidence, or we had independent motivations for them, they would not pass the non-*ad hocness* test of the restricted version of the Likelihood Principle (Section 1.3). Furthermore, from the perspective of probabilistic tension, these alternative design hypotheses typically would generate a corresponding probabilistic tension between the claim that the postulated being had a motive to create a life-permitting world instead of some other type of world and the beings' other attributes, something that does not arise for classical theism (see Section 5.2). Finally, for some of these postulated beings, one could claim that even if LPU confirms their existence, we lack sufficient independent reasons to believe in their existence, whereas for T we have such reasons; or one could claim that they simply transfer the problem of design up one level (see Section 7.1).

The only one of these alternatives that I consider a serious contender is the *axiarchic* hypothesis, versions of which have been advanced in the last 30 years by John Leslie (1989, chap. 8) and recently by Hugh Rice (2000) and others, wherein goodness or ethical "required-ness" has a direct power to bring about concrete reality. Whatever the merits of this hypothesis, it is likely to entail T. Since God is the greatest possible being, it is supremely good that God exists (Leslie 1989, pp. 168–9). Therefore, it is unclear that the axiarchic hypothesis actually conflicts with T.[59] In any case, this chapter has shown that we have solid philosophical grounds for claiming that given the fine-tuning evidence, LPU provides significant support for T over its nonaxiarchic contenders.

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