God, Design, and Fine-Tuning

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I. INTRODUCTION

The Evidence of Fine-tuning

Suppose we went on a mission to Mars, and found a domed structure in which everything was set up just right for life to exist. The temperature, for example, was set around 70^o F and the humidity was at 50%; moreover, there was an oxygen recycling system, an energy gathering system, and a whole system for the production of food. Put simply, the domed structure appeared to be a fully functioning biosphere. What conclusion would we draw from finding this structure? Would we draw the conclusion that it just happened to form by chance? Certainly not. Instead, we would unanimously conclude that it was designed by some intelligent being. Why would we draw this conclusion? Because an intelligent designer appears to be the only plausible explanation for the existence of the structure. That is, the only alternative explanation we can think of--that the structure was formed by some natural process--seems extremely unlikely. Of course, it is *possible* that, for example, through some volcanic eruption various metals and other compounds could have formed, and then separated out in just the right way to produce the "biosphere," but such a scenario strikes us as extraordinarily unlikely, thus making this alternative explanation unbelievable.

The universe is analogous to such a "biosphere," according to recent findings in physics. Almost everything about the basic structure of the universe--for example, the fundamental laws and parameters of physics and the initial distribution of matter and energy--is balanced on a razor's edge for life to occur. As eminent Princeton physicist Freeman Dyson notes, "There are many . . . lucky accidents in physics. Without such accidents, water could not exist as liquid, chains of carbon atoms could not form complex organic molecules, and hydrogen atoms could not form breakable bridges between molecules" (1979, p. 251)--in short, life as we know it would be impossible.

Scientists and others call this extraordinary balancing of the fundamental physical structure of the universe for life the "fine-tuning of the cosmos." It has been extensively discussed by philosophers, theologians, and scientists, especially since the early 1970s, with many articles and books written on the topic. Today, many consider it as providing the most persuasive current argument for the existence of God For example, theoretical physicist and popular science writer Paul claims that with regard to basic structure of the universe, "the impression of design is overwhelming" (Davies, 1988, p. 203).

Many examples of this fine-tuning can be given.[(2)] One particularly important category of fine-tuning is that of the *constants* of physics. The constants of physics are a set of fundamental numbers that, when plugged into the laws of physics, determine the basic structure of the universe. An example of such a constant is the gravitational constant G that is part of Newton's law of gravity, $F = GM_1M_2/r^2$. G essentially determines the strength of gravity between two masses. If one were to double the value of G, for instance, then the force of gravity between any two masses would double.

So far, physicists have discovered four forces in nature - gravity, the weak force, electromagnetism, and the strong nuclear force that binds protons and neutrons together in an atom. Each of these forces has its own coupling constant that determines its strength, in analogy to the gravitational constant G. Using one of the standard dimensionless measures of force strengths (Barrow and Tipler, 1986, pp. 293-295), gravity is the weakest of the forces, and the strong nuclear force is the strongest, being a factor of 10^{40} - or ten thousand billion, billion, billion, billion - times stronger than gravity.

Various calculations show that the strength of each of the forces of nature must fall into a very small life-permitting region for intelligent life to exist. As our first example, consider gravity. If we increased the strength of gravity on earth a billionfold, for instance, the force of gravity would be so great that any land-based organism anywhere near the size of human beings 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.) 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." (Rees, 2000, p. 30). Now, the above argument assumes that the size of the planet on which life formed would be an earth-sized planet. Could life forms of comparable intelligence to ourselves develop on a much smaller planet in such a strong-gravity world? The answer is no. A planet with a gravitational pull of a thousand times that of earth -- which would make the existence of organisms of our size very improbable-- would have a diameter of about 40 feet or 12 meters, once again not large enough to sustain the sort of large-scale ecosystem necessary for organisms like us to evolve. Of course, a billion-fold increase in the strength of gravity is a lot, but compared to the total range of strengths of the forces in nature (which span a range of 10^{40} as we saw above), this still amounts to a fine-tuning of one part in 10^{31}. (Indeed, other calculations show that stars with life-times of more than a billion years, as compared to our sun's life-time of ten billion years, could not exist if gravity were increased by more than a factor of 3000. This would have significant intelligent life-inhibiting consequences.)[(3)]

On the other hand, if the strong force were slightly increased or decreased, the existence of complex life would be seriously inhibited, if not rendered impossible. For instance, using the latest equations and codes for stellar evolution and nucleosynthesis, Heinz Oberhummer, et. al., showed that a small increase or decrease in the strong force - by as little as 1% -- would drastically decrease, by thirty to a thousandfold, either the total amount of carbon or oxygen formed in stars (Oberhummer, et al, 2000, p. 88). Since the carbon and oxygen on planets comes from previous stars that have exploded or blown off their outer layers, this means that very little oxygen would be available for the existence of carbon-based life. At the very least, this would have a life-inhibiting effect given the many important, and seemingly irreplaceable, roles oxygen plays in living processes, such as that of being essential for water (Denton, 1998, pp. 19 - 47, 117 - 140). Other arguments can be given for the other two forces - the electromagnetic force and the weak force -- being fine-tuned, but we do not have space to provide the evidence here. (See, however, my "Evidence for Fine-tuning," in *God and Design,* Neil Manson (ed.), Routledge, Forthcoming.)

There are other cases of the fine-tuning of the constants of physics besides the strength of the forces, however. Probably the most widely discussed among physicists and cosmologists - and esoteric-- is the fine-tuning of what is known as the *cosmological constant.* The cosmological constant was a term that Einstein included in his central equation of his theory of gravity - that is, general relativity -- which today is thought to correspond to the energy density of empty space. A positive cosmological constant acts as a sort of anti-gravity, a repulsive force causing space itself to expand. If the cosmological constant had a significant positive value, space would expand so rapidly that all matter would quickly disperse, and thus galaxies, stars, and even small aggregates of matter could never form. The upshot is that it must fall exceedingly close to zero for complex life to be possible in our universe.

Now, the fundamental theories of particle physics set a natural range of values for the cosmological constant. This natural range of values, however, is at least 10^{53} - that is, one followed by fifty three zeros - times the range of life-permitting values. That is, if 0 to L represent the range of life-permitting values, the theoretically possible range of values is at least 0 to 10^{53}L. [(4)] To intuitively see what this means, consider a dartboard analogy: suppose that we had a dart board that extended across the entire visible galazy, with a bull's eye on the dart board of less than an inch in diameter. The amount of fine-tuning of the cosmological constant could be compared to randomly throwing a dart at the board and landing exactly in the bull's-eye!

Further examples of the fine-tuning of the fundamental constants of physics can also be given, such as that of mass difference between the neutron and the proton. If, for example, the mass of the neutron were slightly increased by about one part in seven hundred, stable hydrogen burning stars would cease to exist. (Leslie, 1989, pp. 39 - 40, Collins, EFT, forthcoming.)

Besides the constants of physics, however, there is also the fine-tuning of the laws. If the laws of nature were not just right, life would probably be impossible. For example, consider again the four forces of nature. If gravity did not exist, masses would not clump together to form stars or planets, and hence the existence of complex, intelligent life would be seriously inhibited, if not rendered impossible; if the electromagnetic force didn't exist, there would be no chemistry; if the strong force didn't exist, protons and neutrons could not bind together and hence no atoms with atomic number greater than hydrogen would exist; and if the strong force were a long-range force (like gravity and electromagnetism) instead of a short range force that only acts between protons and neutrons in the nucleus, all matter would either almost instantaneously undergo nuclear fusion and explode or be sucked together forming a black hole.

Similarly, other laws and principles are necessary for complex life: as prominent Princeton physicist Freeman Dyson points out (1979, p. 251), if the Pauli-exclusion principle did not exist, which dictates that no two fermions can occupy the same quantum state, all electrons would occupy the lowest atomic orbit, eliminating complex chemistry; and if there were no quantization principle, which dictates that particles can only occupy certain discrete allowed quantum states, there would be no atomic orbits and hence no chemistry since all electrons would be sucked into the nucleus.

Finally, in his book *Nature's Destiny*, biochemist Michael Denton extensively discusses various higher-level features of the natural world, such as the many unique properties of carbon, oxygen, water, and the electromagnetic spectrum, that are conducive to the existence of complex biochemical systems. As one of many examples Denton presents, both the atmosphere and water are transparent to electromagnetic radiation in a thin band in the visible region, but nowhere else except radio waves. If instead either of them absorbed electromagnetic radiation in the visible region, the existence of terrestrial life would be seriously inhibited, if not rendered impossible. (pp. 56 - 57)

Thus, the evidence for fine-tuning is extensive, even if one has doubts about some individual cases. 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). Imaginatively, one could think of each instance of fine-tuning mentioned above as a radio dial: unless all the dials are set exactly right, complex, intelligent life would be impossible Or, one could think of the values of the initial conditions of the universe and the constants of physics as coordinates on a dart board that fills the whole galaxy, and the conditions necessary for life to exist as an extremely small target, say less than a trillionth of an inch: unless the dart hits the target, complex life would be impossible. The fact that the dials are perfectly set, or the dart has hit the target, strongly suggests that some intelligent being set the dials or aimed the dart, for it seems enormously improbable that such a coincidence could have happened by chance.

A Preliminary Distinction

Many people take the evidence mentioned above, along with the dart-board analogy, as sufficient reason to infer to theism as the best explanation of the fine-tuning. In this paper, however, I will attempt to make the argument more rigorous. To rigorously develop the fine-tuning argument, we will find it useful to distinguish between what I shall call the *atheistic single-universe hypothesis* and the *many-universes hypothesis*.[(5)] According to the atheistic single-universe hypothesis, there is only one universe, and it is ultimately an inexplicable, "brute" fact that the universe exists and is fine-tuned. Many atheists, however, advocate another hypothesis, one which attempts to explain how the seemingly improbable fine-tuning of the universe could be the result of chance. This hypothesis could be called the *many-worlds hypothesis*, or *the many-universes hypothesis*. According to the most popular version of this hypothesis, there exists some physical process that could be imaginatively thought of as a "universe generator" that produces a very large or infinite number of universes, with each universe having a randomly selected set of initial conditions and values for the constants of physics. Because this generator produces so many-universes, just by chance it will eventually produce one that is fine-tuned for intelligent life to occur.

Given this distinction, we will next attempt to rigorously develop the argument from fine-tuning against the atheistic single universe hypothesis, and then consider four major objections to it. Finally, in section IV we will consider the many-universes hypothesis and some theistic responses to it.

II. Argument Against Atheistic Single-Universe Hypothesis

In this section, we will attempt to rigorously develop the argument for preferring theism over the atheistic single-universe hypothesis. It should be stressed, however, that the soundness of the inference to design based on the fine-tuning does not crucially depend on the ability to make this argument rigorous. We accept many inferences in science, yet philosophers have worked without success for over a century in making these inferences philosophically rigorous. Of course, the skeptic might object that scientific theories are testable, whereas the theistic explanation of the fine-tuning is not. But why should testability be epistemically relevant? After all, testability is about being able to find evidence against a theory in the future. What matters for the likelihood of an hypothesis's truth (or empirical adequacy), however, is the current evidence in its favor, not whether it is possible to find evidence against it in the future.

In order to show inference to design based on the fine-tuning is flawed, skeptics must show that it is based on a manifestly problematic form of reasoning. Indeed, a typical atheist objection against the design argument, going back to the famous Scottish philosopher David Hume, is to cast it as an argument from analogy, and then to argue that arguments from analogy in this context are fatally flawed. As we will show below, however, the argument from fine-tuning can be cast into a form that is very different from the argument from analogy, a form that is difficult to refute. This should go a long way both toward making the argument rigorous and toward answering the criticism of some skeptics that the fine-tuning argument relies on a manifestly flawed form of reasoning.

Although the fine-tuning argument against the atheistic single-universe hypothesis can be cast in several different forms - such as inference to the best explanation - I believe the most rigorous way of formulating the argument is in terms of what I will call the *prime principle of confirmation* (PPC), and which Rudolph Carnap has called the "*increase in firmness"* principle, and others have simply called the *likelihood principle.*[(6)] The prime principle of confirmation is a general principle of reasoning which tells us when some observation counts as evidence in favor of one hypothesis over another. *Simply put, the principle says that whenever we are considering two competing hypotheses, an observation counts as evidence in favor of* *the hypothesis under which the observation has the highest probability (or is the least improbable)*. (Or, put slightly differently, the principle says that whenever we are considering two competing hypotheses, H_1 and H_2, an observation, O, counts as evidence in favor of H_1 over H_2 if O is more probable under H_1 than it is under H_2.) Moreover, the degree to which the evidence counts in favor of one hypothesis over another is proportional to the degree to which the observation is more probable under the one hypothesis than the other.[(7)] For example, I will argue that the fine-tuning is much, much more probable under the theism than under the atheistic single-universe hypothesis , so it counts as strong evidence for theism over this atheistic hypothesis. In the next major subsection, we will present a more formal and elaborated rendition of the fine-tuning argument in terms of the prime principle. First, however, let's look at a couple of illustrations of the principle and then present some support for it.

For our first illustration, suppose that I went hiking in the mountains, and found underneath a certain cliff a group of rocks arranged in a formation that clearly formed the pattern "Welcome to the mountains Robin Collins." One hypothesis is that, by chance, the rocks just happened to be arranged in that pattern--ultimately, perhaps, because of certain initial conditions of the universe. Suppose the only viable alternative hypothesis is that my brother, who was in the mountains before me, arranged the rocks in this way. Most of us would immediately take the arrangements of rocks to be strong evidence in favor of the "brother" hypothesis over the "chance" hypothesis. Why? Because it strikes us as extremely *improbable* that the rocks would be arranged that way by chance, but *not improbable* at all that my brother would place them in that configuration. Thus, by the prime principle of confirmation we would conclude that the arrangement of rocks strongly supports the "brother" hypothesis over the chance hypothesis.

Or consider another case, that of finding the defendant's fingerprints on the murder weapon. Normally, we would take such a finding as strong evidence that the defendant was guilty. Why? Because we judge that it would be *unlikely* for these fingerprints to be on the murder weapon if the defendant was innocent, but *not unlikely* if the defendant was guilty. That is, we would go through the same sort of reasoning as in the above case.

Finally, several things can be said in favor of the prime principle of confirmation. First, many philosophers think that this principle can be derived from what is known as the *probability calculus*, the set of mathematical rules that are typically assumed to govern probability. Second, there does not appear to be any case of recognizably good reasoning that violates this principle. Finally, the principle appears to have a wide range of applicability, undergirding much of our reasoning in science and everyday life, as the examples above illustrate. Indeed, some have even claimed that a slightly more general version of this principle undergirds all scientific reasoning. Because of all these reasons in favor of the principle, we can be very confident in it.

Further Development of Argument

To further develop the core version of the fine-tuning argument, we will summarize the argument by explicitly listing its two premises and its conclusion:

Premise 1. The existence of the fine-tuning is not improbable under theism.

Premise 2. The existence of the fine-tuning is very improbable under the atheistic single-universe hypothesis.[(8)]

Conclusion: From premises (1) and (2) and the prime principle of confirmation, it follows that the fine-tuning data provides strong evidence to favor of the design hypothesis over the atheistic single-universe hypothesis.

At this point, we should pause to note two features of this argument. First, the argument does not say that the fine-tuning evidence proves that the universe was designed, or even that it is likely that the universe was designed. Indeed, of itself it does not even show that we are epistemically warranted in believing in theism over the atheistic single-universe hypothesis. In order to justify these sorts of claims, we would have to look at the full range of evidence both for and against the design hypothesis, something we are not doing in this paper. Rather, the argument merely concludes that the fine-tuning strongly *supports* theism *over* the atheistic single-universe hypothesis.

In this way, the evidence of fine-tuning argument is much like fingerprints found on the gun: although they can provide strong evidence that the defendant committed the murder, one could not conclude merely from them 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 this case, the fingerprints would still count as significant evidence of guilt, but this evidence would be counterbalanced by the testimony of the witnesses. Similarly the evidence of fine-tuning strongly supports theism over the atheistic single-universe hypothesis, though it does not itself show that everything considered theism is the most plausible explanation of the world.

The second feature of the argument we should note is that, given the truth of *the prime principle of confirmation*, the conclusion of the argument follows from the premises. Specifically, if the premises of the argument are true, then we are guaranteed that the conclusion is true: that is, the argument is what philosophers call *valid*. Thus, insofar as we can show that the premises of the argument are true, we will have shown that the conclusion is true. Our next task, therefore, is to attempt to show that the premises are true, or at least that we have strong reasons to believe them.

Support for the Premises

Support for Premise (1).

Premise (1) is easy to support and fairly uncontroversial. The argument in support of it can be simply stated as follows: *since God is an all good being, and it is good for intelligent, conscious beings to exist, it not surprising or improbable that God would create a world that could support intelligent life.* Thus, the fine-tuning is not improbable under theism, as premise (1) asserts.

Support for Premise (2).

Upon looking at the data, many people find it very obvious that the fine-tuning is highly improbable under the atheistic single-universe hypothesis. And it is easy to see why when we think of the fine-tuning in terms of the analogies offered earlier. In the dart-board analogy, for example, the initial conditions of the universe and the fundamental constants of physics can be thought of as a dart- board that fills the whole galaxy, and the conditions necessary for life to exist as a small one-foot wide target. Accordingly, from this analogy it seems obvious that it would be highly improbable for the fine-tuning to occur under the atheistic single-universe hypothesis--that is, for the dart to hit the board by chance.

Typically, advocates the fine-tuning argument are satisfied with resting the justification of premise (2), or something like it, on this sort of analogy. Many atheists and theists, however, question the legitimacy of this sort of analogy, and thus find the argument unconvincing. Although a full scale, rigorous justification of premise (2) is beyond the scope of this paper, we will briefly sketch how such a further justification could be given in section III below, under objection (5).

III. SOME OBJECTIONS TO CORE VERSION

As powerful as the fine-tuning argument against the atheistic single-universe hypothesis is, several major objections have been raised to it by both atheists and theists. In this section, we will consider these objections in turn.

Objection 1: 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 under which the constants of physics *must* have the values they do. Thus, given such a law, it is not improbable that the known constants of physics fall within the life-permitting range.

Besides being entirely speculative, the problem with postulating such a law is that it simply moves the improbability of the fine-tuning up one level, to that of the postulated physical law itself. As astrophysicists Bernard Carr and Martin Rees note "even if all apparently anthropic coincidences could be explained [in terms of some grand unified theory], it would still be remarkable that the relationships dictated by physical theory happened also to be those propitious for life" (1979, p. 612).

A similar sort of response can be given to the claim that the 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 above, however, this postulate simply transfers the improbability up one level: of all the laws and constants of physics that conceivably could have been logically necessary, it seems highly improbable that it would be those that are life-permitting.[(9)]

Objection 2: Other Forms of Life Objection

Another objection people commonly raise against the fine-tuning argument is that as far as we know, other forms of life could exist even if the constants of physics were different. So, it is claimed, the fine-tuning argument ends up presupposing that all forms of intelligent life must be like us. One answer to this objection is that many cases of fine-tuning do not make this presupposition. Consider, for instance, the cosmological constant. If the cosmological constant were much larger than it is, matter would disperse so rapidly that no planets, and indeed no stars could exist. Without stars, however, there would exist 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 life forms of comparable intelligence to ourselves requires some stable energy source. This is certainly a very reasonable assumption.

Of course, if the laws and constants of nature were changed enough, other forms of embodied intelligent life might be able to exist of which we cannot even conceive. But this is irrelevant to the fine-tuning argument since the judgement of improbability of fine-tuning under the atheistic single-universe hypothesis only requires that, given our current laws of nature, the life-permitting range for the values of the constants of physics (such as gravity) is small compared to the *surrounding* range of non-life-permitting values.

Objection 3. **Anthropic Principle Objection**:

According to the weak version of so-called *anthropic principle*, if the laws of nature were not fine-tuned, we would not be here to comment on the fact. Some have argued, therefore, that the fine-tuning is not really *improbable or surprising* at all under atheism, but simply follows from the fact that we exist. The response to this objection is to simply restate the argument in terms of our existence: our existence as embodied, intelligent beings is extremely unlikely under the atheistic single-universe hypothesis (since our existence requires fine-tuning), but not improbable under theism. Then, we simply apply the prime principle of confirmation to draw the conclusion that *our existence* strongly confirms theism over the atheistic single-universe hypothesis.

To further illustrate this response, consider the following "firing-squad" analogy. As John Leslie (1988, p. 304) points out, if fifty sharp shooters all miss me, the response "if they had not missed me I wouldn't be here to consider the fact" is not adequate. 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 my continued existence would be very improbable under the hypothesis that they missed me by chance, but not improbable under the hypothesis that there was some reason why they missed me. Thus, by the prime principle of confirmation, my continued existence strongly confirms the latter hypothesis.

Objection 4: The "Who Designed God?" Objection

Perhaps the most common objection that atheists raise to the argument from design, of which the fine-tuning argument is one instance, is that postulating the existence of God does not solve the problem of design, but merely transfers it up one level. Atheist George Smith, for example, claims that

If the universe is wonderfully designed, surely God is even more wonderfully designed. He must, therefore, have had a designer even more wonderful than He is. If *God* did not require a designer, then there is no reason why such a relatively less wonderful thing as the universe needed one. (1980, p. 56.)

Or, as philosopher J. J. C. Smart states the objection:

> 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) . . . .*If the theist can show the atheist that postulating God actually reduces the complexity of one's total world view, then the atheist should be a theist*. (pp. 275-276; italics mine)

The first response to the above atheist objection is to point out that the atheist claim that the designer of an artifact must be as complex as the artifact designed is certainly not obvious. But I do believe that their claim has some intuitive plausibility: for example, in the world we experience, organized complexity seems only to be produced by systems that already possess it, such as the human brain/mind, a factory, or an organisms' biological parent.

The second, and better, response is to point out that, at most, the atheist objection only works against a version of the design argument that claims that all organized complexity needs an explanation, and that God is the best explanation of the organized complexity found in the world. The version of the argument I presented against the atheistic single-universe hypothesis, however, only required that the fine-tuning be more probable under theism than under the atheistic single-universe hypothesis. But this requirement is still met even if God exhibits tremendous internal complexity, far exceeding that of the universe. Thus, even if we were to grant the atheist assumption that the designer of an artifact must be as complex as the artifact, the fine-tuning would still give us strong reasons to prefer theism over the atheistic single-universe hypothesis.

To illustrate, consider the example of the "biosphere" on Mars presented at the beginning of this paper. As mentioned above, the existence of the biosphere would be much more probable under the hypothesis that intelligent life once visited Mars than under the chance hypothesis. Thus, by the prime principle of confirmation, the existence of such a "biosphere" would constitute strong evidence that intelligent, extraterrestrial life had once been on Mars, even though this alien life would most likely have to be much more complex than the "biosphere" itself.

The final response theists can give to this objection is to show that a supermind such as God would *not* require a high degree of unexplained organized complexity to create the universe. Although I have presented this response elsewhere (unpublished manuscript), presenting it here is beyond the scope of this paper. Here I simply note that, for reasons entirely independent of the argument from design, God has been thought to have little, if any internal complexity. Indeed, Medieval philosophers and theologians often went as far as advocating the doctrine of Divine Simplicity, according to which God is claimed to be absolutely simple, without any internal complexity. So, atheists who push this objection have a lot of arguing to do to make it stick.

Objection 5: No Probability Objection

Some philosophers object to claim that the fine-tuning is highly improbable under the atheistic single-universe hypothesis (that is, premise (2) above) by arguing that since we only have one universe, the notion of the fine-tuning of the universe being probable or improbable is meaningless. Further, they argue, even if it were meaningful, we would have no way of adequately justifying, besides appealing to intuition, that the fine-tuning is very improbable under the atheistic single-universe hypothesis. Typically, the claim behind the first part of this objection is that probability only makes sense in terms of relative frequency among some reference class. Thus, for instance, the assertion that the probability that a randomly selected male smoker will die of lung cancer is 30% means that the 30% of the members of the class of male smokers die of lung cancer. But, if there is only one universe, there is no reference class of universes to compare it to, and hence claims regarding the probability or improbability of fine-tuning in this context do not make sense.

The problem with this argument is that it completely ignores other well-developed conceptions of probability. One of these is the epistemic notion of probability. *Epistemic probability* is a widely-recognized type of probability that applies to claims, statements, and hypotheses--that is, what philosophers call *propositions*. [10] Roughly, the epistemic probability of a proposition can be thought of as the degree of credence--that is, degree of confidence or belief--we rationally should have in the proposition. Put differently, epistemic probability is a measure of our rational degree of belief under a condition of ignorance concerning whether a proposition is true or false. For example, when one says that the special theory of relativity is probably true, one is making a statement of epistemic probability. After all, the theory is actually either true or false. But, we do not know for sure whether it is true or false, so we say it is probably true to indicate that we should put more confidence in its being true than in its being false.

Besides epistemic probability simpliciter, philosophers also speak of what is known as the *conditional* epistemic probability of one proposition on another. (A proposition is any claim, assertion, statement, or hypothesis about the world). The conditional epistemic probability of a proposition *R* on another proposition *S*--written as P(R/S)--can be defined as the degree to which the proposition *S of itself* should rationally lead us to expect that *R* is true. Under the epistemic conception of probability, therefore, the statement that *the fine-tuning of the cosmos is very improbable under the atheistic single-universe hypothesis* makes perfect sense: it is to be understood as making a statement about the degree to which the atheistic single-universe hypothesis would or should, *of itself*, rationally lead us to expect cosmic fine-tuning.

Now that we know what it means to say that the fine-tuning of one of the constants of physics is very unlikely under the atheistic single-universe hypothesis, it is time to briefly outline how such a statement could be justified. Here I think we need to apply what is known as the *principle of indifference*. Applied to the case at hand, the principle of indifference could be roughly stated as follows: *when we have no reason to prefer any one value of a parameter over other, we should assign equal probabilities to equal ranges of the parameter, given that the parameter in question directly corresponds to some physical magnitude.* [11] Specifically, if the "theoretically possible" range (that is, the range allowed by the relevant background theories) of such a parameter is R and the life-permitting range is r, then the probability is r/R. Suppose, for instance, that the "theoretically possible" range, R, of values for the strength of gravity is zero to the strength of the strong nuclear force between those protons - that is, 0 to $10^{40}G_0$, where G_0 represents the current value for the strength of gravity. As we saw above, the life-permitting range r for the strength of gravity is at most 0 to 10^9G_0. Now, *of itself* (specifically, apart from the knowledge that we exist), the atheistic single-universe hypothesis gives us *no* reason to think that the strength of gravity would fall into the life-permitting region instead of any other part of the theoretically possible region. Thus, assuming the strength of the forces constitute a real physical magnitude, the principle of indifference would state that equal ranges of this force should be given equal probabilities, and hence the probability of it the strength of gravity falling into the life-permitting region would be at most $r/R = 10^9 /10^{40} = 1/10^{31}$.

One major problem with this rough version of the principle of indifference is the well-known Bertrand Paradoxes (e.g., see Weatherford, 1982, p. 56), in which there are two equally good but conflicting parameters that directly correspond to a physical quantity. A famous example of the Bertrand paradox is that of a factory that produces cubes whose sides vary from zero to two inches, which is equivalent to saying that it produces cubes whose volumes vary from zero to eight cubic inches. Given that this is all we know about the factory, the naive form of the principle of indifference implies that we should assign both equal probabilities to equal ranges of volumes *and* equal probabilities to equal ranges of lengths, since both lengths and volumes correspond to actual physical magnitudes. It is easy to see, however, that this leads to conflicting probability assignments - e.g., using lengths, we get a probability of 0.5 of a cube being between zero and one inch in length, whereas using volumes we get a probability of 0.125.

Although many philosophers have taken the Bertrand Paradoxes as constituting a fatal objection to the principle of indifference, one can easily avoid this objection either by restricting the applicability the principle of indifference to those cases in which Bertrand Pardoxes do not arise or by claiming that the probability is somewhere between that given by the two conflicting parameters. This problem of conflicting parameters, however, does not seem to arise for most cases of fine-tuning.

Another problem is the total theoretically possible range R of values a constant of physics could have. This is a difficult issue beyond the scope of this paper to address. Here we simply note that often one can make plausible estimates of a lower bound for the theoretically possible range - e.g., since the actual range of forces in nature span a range of 10^{40}, the value of 10^{40} provides a natural lower bound for the theoretically possible range of forces strengths.[12]

Finally, several powerful reasons can be offered for its soundness of the principle of indifference if it is restricted in the ways explained above. 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]"(p. 35). Second, at least for the discrete case, the principle can be given a significant theoretical grounding in information theory, being derivable from Shannon's important and well-known measure of *information*, or *negative entropy* (Sklar, p. 191; van Fraassen, p. 345.). Third, in certain everyday cases the principle of indifference seems the only justification we have for assigning probability. To illustrate, suppose that in the last ten minutes a factory produced the first fifty-sided die ever produced. Further suppose that every side of the die is (macroscopically) perfectly symmetrical with every other side, except for there being different numbers printed on each side. (The die we are imagining is like a fair six-sided die except that it has fifty 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 fifty. Yet, we do not know this directly from experience with fifty-sided dies, since by hypothesis no one has yet rolled such dies 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 the die will land on one side over any other side, and thus we assign them all an equal probability of one in fifty.(13)

Although we have only had space to provide a brief sketch of how one could go about rigorously defending the claim that the fine-tuning is very improbable under the atheistic single-universe hypothesis, the above brief sketch does show, I believe, that there is an initially plausible method available of rigorously supporting our intuitive judgement of the improbability of fine-tuning under the atheistic single-universe hypothesis. Nonetheless, it should be stressed again that even if ultimately our method of support fails, this is not fatal to the fine-tuning arguments. As with arguments in science, the fine-tuning argument has great initial intuitive plausibility. Accordingly, to defeat this initial plausibility, the burden is on the skeptic to show that the fine-tuning argument rests on a clearly faulty form of reasoning.

IV. THE MANY-UNIVERSES HYPOTHESIS

The Many-Universes Hypothesis Explained

In response to this theistic or intelligent design explanation of the fine-tuning, many atheists have offered an alternative explanation, what I will call the *many-universes hypothesis,* but which in the literature goes under a variety of names, such as many-worlds hypothesis, the many-domains hypothesis, the world-ensemble hypothesis, the multi-universe hypothesis, etc. According to this hypothesis, there are a very large--perhaps infinite --number of universes, with the constants of physics varying from universe to universe.(14) Of course, in the vast majority of these universes the constants of physics would *not* have life-permitting values. Nonetheless, in a small proportion of universes they would, and consequently it is no longer improbable that universes such as ours exist in which the constants of physics have just the right values for intelligent life.

Further, usually these universes are thought to be produced by some sort of physical mechanism, which I call a many-universe generator. The universe generator can be thought of as analogous to a lottery ticket generator: just as it would be no surprise that a winning number is eventually produced if enough tickets are generated, it would be no surprise that a universe fine-tuned for life would occur if enough universes are generated.(15)

The Inflationary Many-Universe Model

Most many-universes models are entirely speculative, having little basis in current physics. One many-universe model, however, does have a reasonable basis in current physics - namely, that based on inflationary cosmology. Inflationary cosmology is a currently widely discussed cosmological theory that attempts to explain the origin of the universe. Essentially, it claims that our universe was formed by a small area of pre-space being massively blown up by an hypothesized *inflaton* field, in much the same way as a soup bubble would form in an ocean full of soap. In chaotic inflation models__widely considered the most plausible- various points of the pre-space are randomly blown up, forming innumerable bubble universes. Further, because of the inflaton field, the pre-space expands so rapidly that it becomes a never ending source of bubble universes, much as a rapidly expanding ocean full of soap would become a never ending source of soap bubbles. Thus, inflationary cosmology can naturally give rise to many universes.(16)

In order to get the initial conditions and constants of physics to vary from universe to universe, as they must do if this scenario is going to explain the fine-tuning, there must be a further physical mechanism to cause the variation. Such a mechanism *might* be given by superstring theory, but it is too early to tell. Superstring theory is currently one of the most hotly discussed hypotheses about the fundamental structure of the physical universe (Greene, 1999, p. 214). According to superstring theory, the ultimate constituents of matter are strings of energy that undergo quantum vibrations in a 10 (or 11) dimensional space_time, six or seven dimensions of which are "compactified" to extremely small sizes and are hence unobservable. The shape of the compactified dimensions, however, determines the modes of vibration of the strings, and hence the types and masses of fundamental particles, along with many characteristics of the forces between them. Thus, universes in which compactified dimensions have different shapes will have different constants of physics and differing lower-level laws governing the forces. It is presently controversial whether superstring theory allows for significant variation in the shape of the compactified dimensions. If it does, however, it is then possible that an inflationary/superstring scenario could be constructed in which the shape of the compactified dimensions, and hence the constants of physics, underwent enough variation from universe to universe to explain the fine-tuning.(17)

Thus, it is in the realm of real physical plausibility that a viable inflationary/superstring many_universes scenario could be constructed that would account for the fine_tuning of the constants of physics. Nonetheless, it should be noted that despite the current popularity of both inflationary cosmology and superstring theory, both are highly speculative. For instance, as 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 major attraction of string 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, the two cornerstones of modern physics (Greene, 1999, p. 214).

It should be stressed, however, that even if superstring theory or inflationary cosmology turn out to be false, they have opened the door to taking the many_universes explanation of the fine_tuning as a serious physical possibility since some other physical mechanisms could give rise to multiple universes with a sufficiently large number of variations in the constants of physics. The only way we could close this door is if we discovered that the ultimate laws of physics did not allow either many_universes or much variation in the constants and laws of physics among universes.

Theistic Responses to Many-Universe Generator Scenario

One major theistic response to the many-universe generator scenario, whether of the inflationary variety or some other type, is that the "many_universes generator" itself seems to need to be "well_designed" in order to produce life-sustaining universes. After all, even a mundane item like a bread machine, which only produces loaves of bread instead of universes, must be well designed to produce decent loaves of bread. If this is right, then invoking some sort of many-universe generator as an explanation of the fine-tuning only kicks the issue of design up one level, to the question of who designed the many-universe generator.

The inflationary scenario discussed above is a good test case of this line of reasoning. The inflationary/superstring many-universe generator can only produce life-sustaining universes because it has the following "components" or "mechanisms:"

i) A mechanism to supply the energy needed for the bubble universes: This mechanism is the hypothesized inflaton field. By imparting a constant energy density to empty space, as space expands the inflaton field can act "as a reservoir of unlimited energy" for the bubbles (Peacock, 1999, p. 26).

ii) A mechanism to form the bubbles: This mechanism is Einstein's equation of general relativity. Because of its peculiar form, Einstein's equation dictates that space expand at an enormous rate in the presence of a field, such as the inflaton field, that imparts a constant (and homogenous) energy density to empty space. This causes both the bubble universes to form.and the rapid expansion of the pre-space (the "ocean") which keeps the bubbles from colliding.

iii) A mechanism to convert the energy of inflaton field to the normal mass/energy we find in our universe. This mechanism is Einstein's relation of the equivalence of mass and energy combined with an hypothesized coupling between the inflaton field and normal mass/energy fields we find in our universe.

iv) A mechanism that allows enough variation in constants of physics among universes: The most physically viable candidate for this mechanism is superstring theory. As explained above, superstring theory *might* allow enough variation in the variations in the constants of physics among bubble universes to make it reasonably likely that a fine-tuned universe would be produced. The other leading alternatives to string theory being explored by physicists, such as the currently proposed models for Grand Unified Field Theories (GUTS), do not appear to allow for enough variation. [18]

Without all these "components," the many-universe generator would almost certainly fail to produce a single life-sustaining universes. For example, Einstein's equation and the inflaton field harmoniously work together to enormously inflate small regions of space while at the same time both imparting to them the positive energy density necessary for a universe with significant mass-energy and causing the pre-space to expand rapidly enough to keep the bubble universes from colliding. 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.

In addition to the four factors listed above, the inflationary/superstring many-universe generator can only produce life-sustaining universes because the right background laws are in place. For example, as mentioned earlier, 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. [19]

In sum, even if an inflationary/superstring many-universe generator exists, it along with the background laws and principles could be said to be an *irreducibly complex* system, to borrow a phrase from biochemist

Michael Behe (1996), with 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. In the absence of alternative explanations, the existence of such an a system suggests design since it seems very unlikely that such a system would have just the right components by chance. Thus, it does not seem that one can escape the conclusion of design merely by hypothesizing some sort of many-universe generator.

Finally, the many-universe generator hypothesis cannot explain other features of the universe that seem to exhibit apparent design, whereas theism can. For example, many physicists, such as Albert Einstein, have observed that the basic laws of physics exhibit an extraordinary degree of beauty, elegance, harmony, and ingenuity. Nobel Prize winning physicist Steven Weinberg, for instance, devotes a whole chapter of his book Dreams of a Final Theory (Chapter 6, "Beautiful Theories") explaining how the criteria of beauty and elegance are commonly used to guide physicists in formulating the right laws. Indeed, one of most prominent theoretical physicists of this century, Paul Dirac, went so far as to claim that "it is more important to have beauty in one's equations than to have them fit experiment." (1963, p. 47).

Now such beauty, elegance, and ingenuity make sense if the universe was designed by God. Under the atheistic many-universes hypothesis, however, there is no reason to expect the fundamental laws to be elegant or beautiful. As theoretical physicist Paul Davies writes, "If nature is so 'clever' as to exploit mechanisms that amaze us with their ingenuity, is that not persuasive evidence for the existence of intelligent design behind the universe? If the world's finest minds can unravel only with difficulty the deeper workings of nature, how could it be supposed that those workings are merely a mindless accident, a product of blind chance?"(1984, pp. 235-36.)[(20)]

V. Conclusion

In this paper, I have argued that the fine-tuning of the cosmos for life presents provides strong evidence for preferring theism over the atheistic single-universe hypothesis. I then argued that although one can partially explain the fine-tuning of the constants of physics by invoking some sort of many-universe generator, we have good reasons to believe that the many-universe generator itself would need to be well designed, and hence that hypothesizing some sort of many-universe generator only pushes the case for design up one level. The arguments I have offered do not prove the truth of theism, or even show that theism is epistemically warranted or the most plausible position to adopt. To show this would require examining all the evidence both for and against theism, along with looking at all the alternatives to theism. Rather, the arguments in this paper were only intended to show that the fine-tuning of the cosmos offers us significant reasons for preferring theism over atheism, where atheism is understood as not simply the denial of theism, but as also including the denial of any sort of intelligence behind the existence or structure of the universe.

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1. [1] A full-scale treatment of the fine-tuning argument, and related design arguments, will be presented in a book I am currently working on entitled *The Well-Tempered Universe: God, Fine-tuning, and the Laws of Nature*. This paper is an adapted version of an earlier paper, "The Fine-tuning Design Argument," published in *Reason for the Hope Within*, Michael Murray (ed.), Grand Rapids, MI: Eerdmans, 1999. This earlier paper was made possible in part by a Discovery Institute grant for the fiscal year 1997-1998. Further work on this topic - which is incorporated in this version of the paper - was made possible by a year-long fellowship from the Pew Foundation, several grants from the Discovery Institute, and a grant from Messiah College.

2. [2] For a up-to-date analysis of the evidence for fine-tuning, with a careful physical analysis of of what I consider the six strongest cases, see my "The Evidence for Fine-Tuning," in *God and Design*, Neil Manson (ed), Routledge, 2003. More detailed treatments of the cases of fine-tuning cited below are presented in that paper, along with more detailed references to the literature.

3. [3] See Collins, Ibid.

4. [4] The fine-tuning of the cosmological constant is widely discussed in the literature (e.g., see Davies, 1982, 105 -109, Rees, pp. 95 - 102, 154-155.) For an accessible, current discussion, see Collins, EFT, forthcoming.

5. [5] In this paper, I take atheism as more than simply the denial of the God of traditional theism, but as also involving the denial of any overall intelligence that could be considered responsible for the existence or apparent design of the universe.

6. [6] See Carnap (1962). For a basic, but somewhat dated, introduction to confirmation theory and the prime principle of confirmation, see Swinburne, (1973). For literature specifically casting design arguments as likelihood comparisons see Edwards (1992).

7. [7] For those familiar with the probability calculus, a precise statement of the degree to which evidence counts in favor of one hypothesis over another can be given in terms of the odds form of Bayes's Theorem: that is, $P(H_1/E)/P(H_2/E) = [P(H_1)/P(H_2)] \times [P(E/H_1)/P(E/H_2)]$, where P(/) represents the conditional epistemic probability of one proposition on another. The general version of the principle stated here, however, does not require the applicability or truth of Bayes's theorem.

8. [8] To be precise, the fine-tuning refers to the conjunction of the claim that the range of life-permitting values for the constants of physics is small compared to the "theoretically possible" range R for those values *with* the claim that the values actually fall in the life-permitting range. It is only this latter fact that we are arguing is highly improbable under the atheistic single-universe hypothesis.

9. [9] Those with some training in probability theory will want to note that the kind of probability invoked here is what philosophers call *epistemic probability*, which is a measure of the rational degree of belief we should have in a proposition. (See objection (5) below) Since our rational degree of belief in a necessary truth can be less than 1, we can sensibly speak of it being improbable for a given law of nature to exist necessarily. For example, we can speak of an unproven mathematical hypotheses--such as Goldbach's conjecture that every even number greater than 6 is the sum of two odd primes--as being probably true or probably false given our current evidence, even though all mathematical hypotheses are either necessarily true or necessarily false.

10. [10] For an in-depth discussion of epistemic probability, see Swinburne (1973), Hacking, (1975), and Plantinga (1993), chapters 8 and 9.

11. [11] As an example of what it means to directly correspond to some physical magnitude, consider the mass of an object. A physical parameter "m" that designates the mass directly corresponds to a physical

magnitude, whereas a physical parameter "u" that designates that mass squared ($u = m^2$) does not directly correspond to a physical magnitude but is an artificial variable.

12. [12] Such plausible lower bounds are provided for each case of fine-tuning that I discuss in my paper "Evidence for Fine-tuning" (Forthcoming). This issue is also briefly discussed in my "The Fine-Tuning Design Argument" (1999, pp. 69 - 70) and will be discussed in much more depth in the book I am currently working on entitled *The Well-Tempered Universe: God, Fine-Tuning, and the Laws of Nature.*

13. [13] A full-scale defense of the principle of indifference is beyond the scope of this paper, but will be provided in the book on the fine-tuning design argument that I am currently working on. Also, see Schlesinger (1985, chapter 5) for a lengthy defense of the principle. A somewhat more in-depth treatment of the justification of premise (2) than offered here is presented in the appendix of Collins, 1999.

14. [14]I define a "universe" as any region of space-time that is disconnected from other regions in such a way that the constants of physics in that region could differ significantly from the other regions. A more thorough discussion of the many-universes hypothesis is presented in Collins, "The Argument from Design and the Many-Worlds Hypothesis" (2001).

15. [15] Some have proposed what could be called a *metaphysical* many-universe hypothesis, according to which universes are thought to exist on their own without being generated by any physical process. Typically, advocates of this view - such as the late Princeton University philosopher David Lewis (1986) and University of Pennsylvania astrophysicist Max Tegmark (1998) - claim that every possible world exists. According to Lewis, for instance, there exists a reality parallel to our own in which I am president of the United States and a reality 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. Besides being completely speculative (and in many people's mind, outlandish), a major problem with this scenario is that the vast majority of possible universes are ones which are chaotic, just as the vast majority of possible arrangement of letters of a thousand characters would not spell a meaningful pattern. So, the only way that these metaphysical hypotheses can explain the regularity and predictability of our universe, and the fact that it seems to be describable by a few simple laws, is to invoke an "observer selection" effect. That is, Lewis and Tegmark must claim that only universes like ours in this respect could support intelligent life, and hence be observed. The problem with this explanation is that it is much more likely for there to exist local islands of the sort of order necessary for intelligent life than for the entire universe to have such an ordered arrangement. Thus, a randomly selected observer from among the many universes should expect to find herself in a universe with a local island of order surrounded by vast regions of disorder. Accordingly, Lewis and Tegmark's hypotheses do not appear to be able to explain why we, *qua* supposedly generic observers, live in a universe that is highly ordered throughout. (Among others, George Schlesinger (1984) has raised this objection against Lewis's hypothesis. This sort of objection was raised against a similar explanation of the high degree of order in our universe offered by the famous physicist Ludwig Boltzman, and has generally been considered fatal to Boltzman's explanation (Davies, 1974, p. 103).)

16. [16] For a good, accessible overview of inflationary cosmology, see Guth, 1997.

17. [17] I am indebted to Gerald Cleaver, a string theorist at Baylor University, for helpful discussions of this issue. The sort of inflationary/superstring many-universe explanations of the fine-tuning discussed above have been suggested by a number of authors, such as Linde, (1990, PP&IC, p. 306; 1990, IQC, p. 6) and Greene (1999, pp. 355 - 363). To date, however, no one has adequately verified or worked-out the physics of superstring theory or inflationary cosmology, let alone the combination of the two, so this scenario remains highly speculative.

18. [18] The simplest and most studied GUT, SU(5), allows for three differing sets of values for the fundamental constants of physics when the other non-SU(5) Higgs fields are neglected (Linde, PP&IC, p. 33). Including all the other Higgs fields, the number of variations increases to perhaps several dozen (Linde, IQC, p. 6). Merely to account for the fine-tuning of the cosmological constant, however, which is

estimated to be fine-tuned to one part in 10^{53} , would require on the order of 10^{53} variations of the physical constants among universes.

19. [19] Although some of the laws of physics can vary from universe to universe in string theory, these background laws and principles are a result of the structure of string theory and therefore cannot be explained by the inflationary/superstring many-universes hypothesis since they must occur in all universes. 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 atom_like and stable energy sources would almost certainly require aggregates of matter. Thus, the above background laws seem necessary for there to be life in any of the many_universes generated in this scenario, not merely a universe with our specific types of particles and forces.

20. [20] For more on the case for design from the simplicity and beauty of the laws of nature, see part II of my "The Argument from Design and the Many-Worlds Hypothesis" (2001).