Following the common practice in philosophy, I will be reading a paper instead of following an overhead or powerpoint presentation, as the last two speakers did.

Does the Universe Exhibit Design?

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Contrary to much popular belief, I will argue that in the last century, the findings of science, particularly in the area fundamental physics, have significantly pointed in the direction of a subtle, but very intelligent, designer of the cosmos. As well-respected theoretical physicist and popular science writer Paul Davies concludes, when looking at the fundamental structure of the universe, "the impression of design is overwhelming." In this talk, I attempt to give some sense of why someone might claim this. I will focus on four areas in which I think that the universe shows evidence of design. In this sense the talk will be giving an overview of the case for design from physics and cosmology, instead of going into depth on any one aspect. However, feel free to ask me more in-depth questions in the question and answer session. Unlike the previous speakers in this series, I will not be looking at the issue of design in biology.

The four areas for which we will claim that the universe exhibits evidence of design are **[Fig. X]**:

i) The Fine-Tuning of the Cosmos for Life.

ii) The Simplicity and Beauty of the Laws of Nature

iii) The Intelligibility and discoverability of the laws of nature.

iv) The seeming miraculous ability of our minds to understand the fundamental structure of the universe.

I will argue that these four features of our universe provide a cumulative case argument for some sort of design. A cumulative case argument is the sort of argument in which multiple pieces of evidence point toward a single conclusion: even though one piece of evidence alone might not be entirely convincing, the total body of evidence can be quite compelling. Such cumulative case arguments often occur in courtrooms, in which, for instance, multiple lines of evidence, such as fingerprints, blood samples, and the testimony of witnesses might point to the defendant's guilt or innocence. We will begin our cumulative case argument by looking at the case of the fine-tuning of the cosmos for life.

I. The 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

Many examples of this fine-tuning can be given. 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. **[Fig. X]** An example of the 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. As measured between two protons, 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 is balanced balanced on a razor's edge for life to occur. As an example, consider the strong force. Since like charges repel each other, in all atoms except hydrogen, the protons in the atom exert a strong electrostatic repulsive force against each other, thus tending to tear the nuclei apart. Fortunately, the attraction exerted by the strong force overcomes this repulsive force between the protons, thus allowing them to stay together. If the strong force were 50% weaker than its current value, all atoms such as carbon that are essential for life would become unstable; if it were decreased slightly further, all atoms except hydrogen would break apart leaving one with a universe whose only atoms were hydrogen. Contrary to what one might see on *Star Trek*, an intelligent life form cannot be composed merely of hydrogen gas: there is simply not enough stable complexity.**[See Fig. X]**

For a variety of other reasons, if the strong force were slightly increased the existence of life would be seriously inhibited, if not rendered impossible. For instance, a small increase in the strong force - by as little as 1% -- would drastically decrease the total amount of oxygen formed in stars. (Reference) Since the 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. (See Denton, *Nature's Destiny.*) A small increase would also likely have other life-inhibiting, or even eliminating, effects.[(1)]

Now, a 50% decrease in the strong force, or a 1% increase, might not itself seem that impressive, but relative to the total range of variation of the forces, it is extraordinarily small, being one part in ten thousand, billion, billion, billion, billion. To get an idea of how precise this is, it would be like randomly throwing a dart at the surface of the earth from outer space, and hitting a bull's eye one trillionth of an inch in diameter! Another way of imaginatively thinking about this fine-tuning is in terms of a radio dial with ten thousand billion, billion, billion, billion tick marks. In order for life to occur, the dial has to be tuned to one radio station whose frequency lies between two consecutive tick marks. **[See Fig. X]**

As mentioned above, there are solid physical arguments for thinking that all the forces of nature, not just the strong force, must be precisely balanced for life to occur in our universe. There are other cases of fine-tuning 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 10^120 - that is, one followed by one hundred and twenty zeros - greater than the range of life-permitting values. To intuitively see what this means, consider our dartboard analogy once again: suppose that we had a dart board that extended across the entire visible universe (that is, 15 billion light years), with a bull's eye on the dart board of less than a trillionth, trillionth of an inch in diameter. The amount of fine-tuning of the cosmological constant would be equivalent to randomly throwing a dart at the board and landing exactly in the bull's-eye!

Other examples of the fine-tuning of the constants can also be given, such as that of mass difference between the neutron and the proton, which seems to need a fine-tuning of one part in a thousand for life to occur. Besides the constants, however, there is also the fine-tuning of the laws. If the laws of nature were not just right, life would probably be impossible. As just two of many examples, the principle of quantization is responsible for electrons inhabiting well-defined orbits in atoms, instead of being almost immediately sucked into the nucleus, in which case there would be no atoms and hence no chemistry; similarly, the laws governing the strong nuclear force require that it act only over very short distances, unlike gravity and electromagnetism which act over very large distances. If the strong nuclear force were only act over extremely short distances, all solid and liquid matter would almost immediately undergo nuclear fusion, eliminating all the lighter elements on planetary bodies, and probably all solid bodies would either immediately explode or become black holes.

Finally, in his book *Nature's Destiny*, biochemist Michael Denton lists 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. This, Denton argues, suggests design, since it seems extraordinarily coincidental that all these features would occur by chance. Consider, for instance, carbon. **[Fig. X.]** Carbon has at least six features that make it uniquely fit for life, with its nearest competitor, silicon, lacking almost all these features. Because these properties occur so infrequently in other elements, Denton argues, it is quite surprising that a single element has all five of them. It appears as though the laws of nature were designed to produce carbon. Three of the six properties that Denton lists are: (i) unlike any other element, carbon can form long, stable chains; (ii) Unlike silicon, it has an almost equal affinity for a wide variety of other atoms, including itself, and hence can form very diverse and complex stable molecules; And (iii) it has an ideal chemistry in the same temperature range as when water is liquid, with water itself being the liquid which is by far the most conducive for the existence of the sort of complex biochemical reactions necessary for life **[Fig. X].**

Imaginatively, one could think of each instance of fine-tuning mentioned above as a radio dial: unless all the dials are set exactly right, life would be impossible. . **[See Fig. X, Becky Warner.]** 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, 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

Now, it should be noted that although many physicists have argued for an extensive fine-tuning for life of the physical structure of the universe, some physicists have caste doubt on the extent of this purported fine-tuning. I am somewhat sympathetic to the skeptics, having found significant errors in the physical reasoning behind several purported cases of fine-tuning. On the other hand, in most of these cases I have found alternative reasons why the constant in question must be fine-tuned.

One way or another, despite possible errors in the arguments for individual cases of fine-tuning, the large number of independent instances of apparent fine-tuning makes the claim that the universe is fine-tuned for life quite compelling.. 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). Further, the arguments for some of the purported cases of fine-tuning, such as that a small decrease in the strength of the strong nuclear force would cause all atoms except hydrogen to disintegrate, are so straightforward that it is hard to see how they could be in error.

What is more controversial is the degree to which the fine-tuning provides evidence for the existence of God. As impressive as the argument from fine-tuning seems to be, skeptics have raised several significant objections to it. The most widely offered of these objections, and the only one we have time to cover here, is the so-called many-universes hypothesis. This we will turn to next.

II. The Many-Universes Hypothesis Explained

In response to theistic explanation of fine-tuning of the cosmos, many have offered an alternative explanation, what I will call the many-universes hypothesis. Indeed, in standard physics journals, this is the only explanation discussed, and it is taken very seriously by many physicists and cosmologiest. According to this hypothesis, there are a very large--perhaps infinite --number of universes, with the constants of physics varying from universe to universe.[(2)] 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 that are fine-tuned for life to occur.

Further, usually these universes are thought to be produced by some sort of physical mechanism, which I call a many-universe generator. **[Fig. X]**. 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.

Various responses to the many-universe hypothesis could be offered. One simple response is that it takes more faith to believe in these many-universes than in God. Although this response has some merit, as I will explain below, there is at least one currently proposed many-universe generator model that has significant physical plausibility, namely that involving a combination of what is known as inflationary cosmology with superstring theory. Assuming that inflationary cosmology and superstring theory are eventually significantly confirmed by experimental evidence, this response could quickly become quite weak, and hence I would not want to rely on it as my only response.

The second response is to note that even if a "many-universes generator" exists it seems to need to be "well-designed" in order to produce life-sustaining universes. **[See Fig. X**]. 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.

To test this reasoning, we will look at the many-universe generator scenario widely considered the most plausible, that arising out of what is known as inflationary cosmology combined with superstring theory. We will then attempt to show that it must have just the right components to produce even one life-sustaining universe, and so itself appears to need design.

III. Inflationary/Superstring Many-Universe Scenario Explained

Inflationary cosmology is a currently widely discussed cosmological theory that attempts to explain the origin of the universe. [**Fig. X**] 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.

In order to get the initial conditions and paramters 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), and is certainly the only currently viable physical theory that might allow for enough variation among universes of the constants of physics to explain the fine-tuning. 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. **[Fig. X2. Guitar + Diagram].** Thus, combined with inflationary cosmology, superstring theory *might* allow for enough variation in the shape of the compactified dimensions, and hence in the constants of physics, among universes to explain the fine-tuning.

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).[(3)]

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.

Now, I will turn to the case for claiming that the inflationary/superstring many-universe generator appears to need design.

IV. Why the Inflationary Superstring Many-Universe Generator Needs Design.

My argument begins by noting that 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, *Cosmological Physics*, 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 energy density to empty space. This causes the bubble universes to form.and causes the rapid expansion of the 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 viable candidate for this mechanism is superstring theory. 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. Most other proposed fundamental physical theories do not.

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 five factors listed above, the inflationary/superstring many-universe generator can ony 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. [(4)]

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. **[Fig. X]** Thus, it does not seem that one can easily escape the conclusion of design by hypothesizing a some sort of many-universe generator.

It should also be noted that the inflationary scenario does not explain where the mass-energy of the universe, and the laws of physics, came from. The answer that they always existed is most likely ruled out within inflationary scenarios. (See Guth, 1997, p. 249 and Guth, 2000, p. 16.) This suggests a need for a transcendent being that is responsible for the existence of the universe, though we will not pursue this form of the cosmological argument here.

V. Beauty and Simplicity of Laws of Nature

Next, we will turn to the various features of the laws of nature that both suggest design and cannot be explained by *any* many-universes hypothesis, whether a universe generator scenario or something else. The features we will look at in this section are the simplicity and beauty of the laws of nature.

We will begin with the simplicity of the laws. Although no adequate definition of what is meant by calling the laws of nature simple has ever been given, both scientists and philosophers almost unanimously agree that they manifest a surprising degree of simplicity. Indeed, when constructing a new law of nature in some domain, scientists routinely look for the simplest law that adequately accounts for the known data and which meets the other constraints imposed by various background assumptions.

Besides simplicity, there is also the beauty of the laws of nature. As Nobel prize winning theoretical physicist Steven Weinberg stresses in his book *Dreams of a Final Theory* (1992), beauty is widely recognized by physicists as being an important characteristic of the laws of nature, one which has served as a highly successful guide to discovering the fundamental laws of nature in the 20th century. Indeed, Weinberg devotes all of chapter six of his book to discussing and emphasizing the role that considerations of beauty have played in physics. Weinberg, who is a convinced atheist, even admits that "sometimes nature seems more beautiful than strictly necessary" (1992, p. 250).

This use of beauty and elegance as a fundamental guiding principle in physics was to a large extent inaugurated by Einstein in his development of general relativity, though it was certainly implicitly used by earlier physicists. Einstein's leading biographer, Banesh Hoffman, tells us that:

> When judging a scientific theory, his own or another's, he asked himself whether he would have made the universe in this way had he been God. This criterion ... reveals Einstein's faith in an ultimate simplicity and beauty in the universe. Only a man with a profound religious and artistic conviction that beauty was there, waiting to be discovered, could have constructed theories whose most striking attribute, quite overtopping their spectacular success, was their beauty. (Quoted on p. 281, *Fearful Symmetry*)

As a matter of personal testimony, as I have attempted more fully to understand Einstein's theory of general relativity over the last ten years, I have come to realize how enormous a conceptual leap exists between the prior Newtonian theory of gravity and Einstein's, and thus what an enormous conceptual leap was involved in Einstein's developing his theory. For starters, Newton conceived of gravity as a force, whereas Einstein conceived of it as a curvature of a four-dimensional semi-Riemannian geometry, a construction that can only be adequately spelled-out in highly abstract mathematical terms. As theoretical physicist A. Zee has points out, (FS, p. 98), experiment alone could not have guided Einstein to this theory: the conceptual leap is just too large. Rather, something much deeper was at work, which according to Einstein's own testimony involved a conviction that nature must exemplify a certain sort of mathematical and conceptual beauty at the fundamental level.

Following Einstein's lead, Paul Dirac, one of the most important figures in the development of physics in the 20th century, made mathematical beauty the foremost criterion in developing a physical theory. According to theoretical physicist and historian of physics Oliver Darrigol,

> the notion of mathematical beauty was an integral part of ...[Dirac's] strategy. [According to Dirac,] one first had to select the most beautiful mathematics--not necessarily connected to the existing basis of theoretical physics--and then interpret them in physical terms (1992, p. 304).

As Dirac himself said, "it is more important to have beauty in one's equation than to have them fit experiment." (5)Today, this use of beauty and elegance as a guide is particularly evident in the popularity of string theory, which as mentioned above is almost entirely motivated by considerations of elegance, having no experimental support in its favor.

As embodied in the mathematical structure of physical theory, some of these elements of beauty are: (i) simplicity with variety; (ii) proportion and harmony; (iii) symmetry; (iv) inevitability; (v) ingenuity; and (v) having an "interesting twist" or a "strangeness of proportion." (6)

The above elements are largely constitutive of the so-called classical concept or type of beauty, but I will only significantly discuss that of simplicity with variety here. Simplicity with variety was the defining feature of beauty or elegance stressed by William Hogarth in his 1753 classic *The Analysis of Beauty*, where he famously used a line drawn around a cone to illustrate this notion. **[See Fig. X2]**. According to Hogarth, simplicity apart from variety, such as a straight line, is boring, not elegant or beautiful.

Now, the laws of nature seem to manifest just this sort of simplicity with variety: we inhabit a world that could be characterized as a world of fundamental simplicity that gives rise to the enormous complexity needed for intelligent life. In physics, this simplicity with variety is particularly evident in the way in which whole classes of diverse physical phenomena and laws of nature are encompassed by common *contingent* principles of great simplicity and elegance. For instance, consider the so-called gauge principle of fundamental particle physics, which I do not expect anyone in the audiance to understand. This principle undergirds our current understanding of at least three, and arguably all four, of the four forces of nature. The mathematical form of three of the four forces of nature, the strong force, the weak force, and electromagnetism, all obey the gauge principle, and the gauge principle served as a crucial guide in constructing the modern theory of these forces. Further, a principle very much like the gauge principle is what guided Einstein in the construction of his theory of general relativity, which is currently our best theory of the gravitational force. Yet, as Ian Atchison and Anthony Hey point out in their text *Gauge Theories in Particle Physics,* there is no compelling logical reason why this principle must hold (1989, pp. 59- 60). Rather, they claim, this principle has been almost universally adopted as a fundamental principle in elementary particle physicists because it is "so simple, beautiful and powerful (and apparently successful)" (1989, p. 60). Further, as the inventor of inflationary cosmology, Alan Guth, points out, the original "construction of these [gauge] theories was motivated mainly by their mathematical elegance" (1997, p. 124). Thus, the gauge principle provides a good example of a contingent principle of great simplicity and elegance that encompasses a wide range of diverse laws, namely those laws governing each of the four forces in nature. (7)

A few other examples of principles that encompass large classes of diverse phenomena and laws are the law of energy conservation, the least action principle, the second law of thermodynamics, and various quantum principles, such as the superposition principle and the Pauli-exclusion principle. If one were to think about this in terms of an architectural analogy, the physical universe would correspond to the building, and the laws of physics would correspond to the various smaller scale features, such as the windows in the house. The simplicity and elegance of the laws would thus correspond to the elegance of these features. Finally, the fact that the laws of nature are arranged just right way to jointly meet a small set of elegant higher-level principles would be analogous to the the positions of windows, and other features of the building, being arranged just right so as to meet a few higher-level architectural principles of proportion and harmony. This architectual analogy, therefore, illustrates that there are at least two layers of simplicity and elegance in the fundamental mathematical structure of the universe: the laws themselves, and the higher-level patterns into which they fall.

Another way of thinking about the this issue is in terms of fine-tuning. For instance, if one imagines a space of all possible laws, the set of laws we have are just those that meet the higher-level principles. Often you cannot vary them the smallest amount without violating the higher level principles. This is particularly evident in the case of Einstein's general theory of relativity. As Nobel Laureate Steven Weinberg notes, "once you know the general physical principles adopted by Einstein, you understand that there is no other significantly different theory of gravitation to which Einstein could have been led." (1992, p. 135) As Einstein himself said, "To modify it [general relativity] without destroying the whole structure seems to be impossible." (Quoted in Weinberg, 1992, p. 135.) As mentioned above, this sort of fine-tuning occurs in many other areas, such as gauge theories and the way quantum mechanics fits with special relativity.

Of course, in analogy to the case of the fine-tuning of the constants of physics, there are bound to be other sets of laws that meet some other relatively simple set of higher-level principles. But this does not take away from the fine-tuning of the laws, or the case for design, anymore than the fact that there are many possible elegant architectural plans for constructing a house takes away from the design of a particular house. What is important is that the vast majority of variations of these laws end up causing a violation of one of these higher-level principles, as Einstein noted about general relativity. Further, for those who are aware of the relevant physics, it is easy to see that in the vast majority of such cases, such variations do not result in new, equally simple higher-level principles being satisfied. It follows, therefore, that these variations almost universally lead to a less elegant and simple set of higher-level physical principles being met. Thus, in terms of the simplicity and elegance of the higher-level principles that are satisfied, the laws of nature we have appear to be a tiny island surrounded by a vast sea of possible law structures that either produce a far less elegant and simple underlying physics, or which do not generate enough variety to allow for the existence of complex life forms. If one thinks in terms of God's creating the laws of nature, God would have had to choose a tiny speck out of a vast region of possible law structures to produce laws that both meet a simple set of higher-level principles and yet produce enough variety and compelixity of phenomena to allow for complex life. **[Fig. X]**

There is also one other type or level of beauty that needs to be mentioned. That involves the mathematics that are used in physics. As various authors have pointed out, axiomatic systems of implication - such as the complex numbers - are chosen to be part of mathematics based on their beauty. As mathematicians Mark Kac and Stanislaw Ulam point out in their classic book, *Mathematics and Logic*, "The criteria of judgement in mathematics is always aesthetic, at least in part. The mere truth of a proposition is not sufficient to establish it as mathematics. One looks for 'usefulness,' for 'interest,' and also for 'beauty.'" (p. vi). As the famous mathematician G. L. Hardy said, "Beauty is the first test [for mathematics]. There is no permanent place for ugly mathematics." Yet as Weinberg notes, "mathematical stuctures that confessedly are developed by mathematicians because they seek a sort of beauty are often found later to be extraordinarily valuable by physicists." (DFT, p. 153). So beauty plays an additional role in physics, that of being central to the very mathematical structures that undergird our most fundamental physical theories of the universe.

VI. Alternative Explanations of Beauty of Laws of Nature

Alternative Non-design Explanations

Above we have claimed that the beauty of the laws of nature - particularly in their form of simplicity with variety, and how they fall into particularly elegant higher-level patterns- suggests that the universe was designed by a "great artist." But aren't there alternative explanations? [(8)]

The first attempt at an alternative explanation is to claim that this so-called beauty is purely subjective, simply the result of our reading into nature anthropomorphic patterns in the same way as humans have read various meaningful patterns--such as the Bear or the Big Dipper--into the random pattern of stars in the night sky. The major problem with this explanation is that it does not account for the surprising success of the criterion of beauty in the physical sciences. Patterns that are merely subjective do not serve as a basis for highly accurate predictions that are clearly objective, such as quantum electrodynamics's successful prediction, to nine significant digits, of the quantum correction to the g-factor of the electron. The second problem is that there are significant objective aspects of beauty, at least in the classical sense of beauty, that one can clearly demonstrate in the realm of physics, such as that of simplicity with variety and symmetry.

The second attempt at offering an alternative explanation is to invoke evolution, claiming that long before the rise of science, natural selection programmed into us the category of beauty because it was of survival value. Although evolution might be able to explain why we have a category of beauty, it cannot explain why it applies so well to the underlying order of the world, since such applicability was obviously irrelevant to our survival during the long course of human biological evolution. At most, evolution could only explain why beauty applies to the everyday world of those things necessary for our survival, such as attracting mates or getting food. But, as often noted, it is in the underlying world that considerations of beauty as a guide have met with the most impressive success, at least in terms of producing theories that are extraordinarily predictively fruitful. This is just the opposite of what this evolutionary explanation would lead one to expect. Further, this evolutionary explanation leaves unexplained why the underlying world exhibits those objective features--such as simplicity with variety, symmetry, and harmony and proportion--so characteristic of beauty. Theism, in contrast, naturally explains these characteristics.

A second kind of evolutionary explanation is that presented by Steven Weinberg: through a process of trial and error since the scientific revolution, we have learned that nature is a certain way, and then we have come to consider the way nature is beautiful (1992, p. 158). That is, Weinberg suggests that after the scientific revolution, scientists unconsciously modified their criteria of beauty to fit nature. The problem with this explanation is that we can point to objective features of underlying world--its symmetry, its simplicity in variety, its inevitability--that clearly fit the general criteria of the so-called *classical* conception of beauty, a category of great human significance that originated long before the scientific revolution. Further, the mere fact that scientists use the term "beautiful" instead of some other category to describe the underlying order indicates that they sense a deep congruence between the order of nature and those features normally associated with beauty in other, non-scientific contexts. It is this congruence that Weinberg's evolutionary explanation fails to explain.

The third attempt at an alternative explanation is to invoke some metaphysical principle of simplicity -- such as a metaphysical principle which dictates that the basic structure of the world is more likely to be simple than complex -- to account for the simplicity of the laws. This would at least provide the first step in explaining the beauty of the laws. Such a metaphysical principle suffers from several severe problems, however. To name only one, we can imagine much simpler worlds, such as one in which there was just empty space. Thus, under this principle, the existence of a universe as with as much variety and complexity as ours would be very improbable, and hence largely inexplicable. So, it fails to account for the simplicity with variety of the laws of nature.[(9)]

The final alternative is merely to claim that the simplicity and beauty of the laws of nature is simply a brute fact that requires no explanation. One could always adopt this position, but then given that theism naturally explains these features of the laws of nature, the atheist must admit that theism offers a better explanation of them than atheism, and thus that they support theism over atheism. Why? Because a natural, *non-ad hoc* explanation of a phenomenon *x* is always better than no explanation at all. And theism does seem to offer such a natural explanation: for example, given the classical theistic conception of God as the greatest possible being, and hence a being with a perfect aesthetic sensibility, it is not surprising that such a God would create a world of great subtlety and beauty at the fundamental level.

The upshot of this discussion is that the idea that God created the universe provides a much better explanation of the apparent "fine-tuning" of the fundamental laws of nature for elegance and beauty than any non-design hypothesis. Thus this apparent fine-tuning provides evidence for design.

VII. Intelligibility and Discoverability:

Another feature of the fundamental structure of the physical world that seems to suggest design is its intelligibility. As Albert Einstein once remarked, "the most unintelligible thing about the universe is that it is intelligible at all." One aspect of this intelligibility is the fact that those human intuitions, categories and concepts we consider significant apply surprisingly well and serve as surprisingly good guides to the underlying order of things. We have already seen this in the applicability of the categories of simplicity and beauty to the underlying order, which are special cases of this more general notion of the intelligibility of nature. This more general notion also includes human intuitions about the way nature should be, along with additional categories such as naturalness, all of which are central to both theory confirmation and development. As Einstein remarked, "There is no logical path leading to these laws [of nature], but only intuition, supported by sympathetic understanding of experience." (Quoted in Arthur Miller, *Insights of Genius*, p. 369).

A further way in which the laws of nature and the structure of physical reality suggest design is in what I will call their discoverability: that is, the laws of nature seem to be carefully arranged so that they are discoverable by beings with our level of intelligence. I believe that this feature of the laws not only suggests design, but that it fits into a larger pattern that suggests a particular providential purpose for human beings, such as that of developing a sophisticated science and technology, but I cannot argue for that here. (Indeed, as an aside, in his book *Nature's Destiny*, Michael Denton discusses how coincidental it is that nature has the right elements, such as various metals and silicon, to allow for the development of sophisticated technology.)

Of course, the fact that the fundamental structure of the world displays a simplicity, elegance, and intelligibility greatly contribute to its discoverability, as we have indicated above. Although we cannot present them here, more specific examples of this "fine-tuning" for discoverability are presented by philosopher Mark Steiner in his Harvard University Press book, *The Applicability of Mathematics as a Philosophical Problem*, in which he concludes that the world much more "user-friendly" than seems explicable under naturalism (1998, p. 176). Although I do not think that Steiner has yet made an entirely compelling case, it seems to me he is on the right track. As a matter of personal testimony, as I have studied the foundations of quantum mechanics and general relativity, I have been often impressed with how nature seems to be endowed with quite surprising, almost "magical," principles that appear to provide a ladder which has allowed us to move from one conceptual level to another radically different and deeper conceptual level within physics. For example, Einstein relied on such principles when he leapt from the Newtonian framework to that of general relativity , and other physicists did the same when they developed quantum mechanics. It is the existence of such principles, I would argue, that have allowed us to understand the nature of the physical universe at levels of increasing depth and abstraction. We can pursue this issue in the question and answer session if people so desire.

Finally, as even further evidence for some sort of design arises when we reflect on the emergence within our universe of consciousness and highly abstract and theoretical thought as occurs in philosophy, mathematics, and advanced physics, something seemingly inexplicable by an unguided evolutionary process since it does not appear either to have been of any survival value, or to be a natural byproduct of anything of significant survival value, during the long course of human biological evolution.[(10)] This is especially true given the strong case that I believe can be made for the irreducibility of consciousness to physical processes or states.

This problem of unguided evolution explaining our capacity for reliable abstract theoretical thought has been made particularly acute by the extraordinary level of abstraction in contemporary fundamental physics, which is based on concepts and mathematical systems - such as the complex numbers - far removed from experience. Many have pointed to this problem, though I only have time to give you some idea of the gist of this argument thorough a couple of quotations. The first is from prominent philosopher Thomas Nagel, who is himself an atheist. Says Nagel,

> In themselves, the advanced intellectual capacities of human beings, unlike many of their anatomical, physiological, perceptual, and more basic cognitive features, are extremely poor candidates for evolutionary explanation, and would in fact be rendered highly suspect by such an explanation .... the capacity to form cosmological and subatomic theories takes us so far from the circumstances in which are ability to think would have had to pass its evolutionary tests that there would be no reason whatever, stemming from the theory of evolution, to rely on it in extension to those subjects. In fact, if per impossible, we came to believe that our capacity for objective theory were the product of natural selection, that would warrant serious skepticism about its results beyond a very limited and familiar range. (*The View from Nowhere*, Oxford University Press, 1986, p. 79.)

Even Charles Darwin recognized this problem, stating in his Autobiography that:

> The horrid doubt always arises whether the convictions of man's mind, which has developed from the mind of lower animals, are of any value at all or trustworthy. Would anyone trust the conviction of a monkey's mind, if there be any convictions in such a mind?

Although I think this latter argument presents a powerful case for design of our mental faculties (whether a direct design of our mental faculties, or through some sort of guidance of the evolutionary process), I do not have time to develop that case here. Rather, let me summarize the overall case for design in the following overhead.**[Fig. X**]

Possible Ending Here:

As I mentioned, the argument I have offered for design involves what philosophers call a cumulative case argument in which many factors, such as the fine-tuning, the simplicity, the beauty, the intelligibility, and discoverability of the laws of nature, and the existence of minds that can understand the underlying order of nature, all point in the same direction, and seem difficult to explain on any other hypothesis. In this sense, the above case is very similar to the sort of arguments offered for scientific theories, such as the theory of evolution by descent with modification. As evolutionary biologist and geneticist Edward Dodson summarizes the case for evolution,

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" (p. 68).

The case for design as I have presented it is of the same form and, I believe, will be found to be of comparable strength upon further research and elaboration.

NOTES

1. [1] The effect would be to bind the diproton, resulting in all the normal hydrogen turning into deuterium in the early universe. This in turn would cause stars with the same energy output as the sun to be very short-lived, which would seriously decrease the likelihood of life evolving. On the other hand, stars with life-times near that of the sun would be much dimmer with spectrums shifted toward the red end of the spectrum, and with energy outputs less stable. There are good reasons to believe that all these factors would have life-inhibiting effects.

2. [2]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.

3. [3] 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.

4. 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.

5. [5] From, P. A. M. Dirac, "The Evolution of the Physicist's Picture of Nature," *Scientific American*, Vol. 208, May 1963, p. 47.

6. [6] For example, see S. Chandrasekhar, 1987, chapter 4, for a discussion of this criterion. Also see A. Zee, 1986, for a very accessible account of the role that considerations of beauty have played in modern physics.

7. [7] The gauge principle is highly technical and difficult to understand without much advanced training in physics, and thus beyond the scope of this paper to further explain.

8. One possible alternative explanation not discussed below is the many-universes hypothesis. Clearly, the inflationary/superstring many-universe hypothesis will not work, since it simply postulates that underlying all the universes there is a set of elegant laws and principles, namely those underlying string theory; it does not try to explain why these laws exist. To get this explanation to work, one must advocate what could be called a *metaphysical* many-universe hypothesis, according to which all possible law structures are realized in some universe or another. This explanation, however, can be easily dismissed since there is no reason to expect observers only to exist in universes that have an exceedingly elegant underlying order. Thus, it is still a huge coincidence that we, as randomly selected observers among those universes, would live in one with such elegance at a fundamental level. To get this to work, one would have to combine it with a metaphysical principle that nature is more likely to be simple than complex. But even then one would run into severe problems.

9. This principle would also need to be supplemental with a parallel principle to account for the intelligibility and discoverability of the laws of nature, along with a many-universes hypothesis to account for the fine-tuning for life of the constants of physics. The only way I can see of making the existence of such principles plausible is by appealing to some unified overarching hypothesis that implies these lower-level principles, such as the theistic hypothesis.

10. [10] The argument that unguided naturalistic evolution cannot explain human consciousness or our capacity for theoretical reasoning has been advocated by both atheists and theists. See, for instance, Paul Davies (1993), Thomas Nagel (1997, pp. 130 - 143), and Alvin Plantinga (1993, chapter 12).