ODFR March 7-- David Snoke
"Should we be surprised? Large-numbers coincidences in cosmology"

To start, one may ask why we should be interested in cosmology. I am not a cosmologist, so why am I interested in cosmology?

In my experience, the entire Argument from Design starts with the statement, "I think that I shall never see, a thing as lovely as a tree." Some people (including myself) see design in things around us, such as trees or the human eye, etc. This argument is as old as civilization. The modern atheistic response is Darwinism, which says that the beauty of a tree is not a product of design, but just a probable outcome of evolution, given the existence of DNA. But then one can ask, "Whence DNA?" DNA seems to be designed to many people; it is full of information with a highly specific purpose. The atheist answer is that given the proper conditions on the ancient earth (such as the proper kind of mud) the spontaneous assembly of DNA via natural causes is probable. This is far from proven, but supposing one accepts this, one can still ask, "What is the likelihood of an earth which produces DNA?" An earth which produced DNA automatically would seem to have to be highly "rigged," that is, designed. The atheist may answer, "Given the proper type of stars, this type of planet is likely in the universe." Then one may ask, "what is the likelihood of the right type of starts?" The atheist may answer, "Given the structure of the universe, this type of star is likely." This pushes the question all the way back to the structure of the universe, that is, cosmology. Beyond this, we cannot go. Therefore all arguments about design seem to end up with cosmology.

Types of "Large Numbers Paradoxes"

There are actually several different types of paradoxes.

1. Large free parameters are intrinsically bothersome

Eddington and Dirac were two famous scientists in the early 1900's who noticed that the laws of physics have several constants which are essentially "fit parameters" with no fundamental cause based on geometry or other first principles. Physicists hate theories with a large number of fit parameters, because they seem "rigged." Dirac wanted all constants of nature to be formed from combinations of 4π, e, the square root of two, etc. But the ratio of some parameters in unitless numbers is often very large, e.g. the ratio of the electric to the gravity force for two electrons is 10^{40}. It is hard to imagine how one can get unitless ratios of fundamental parameters which vary by factors like this just built out of factors of 4π.

Dirac's proposal was that the constants of nature are not constant, but vary in time, so that the ratio 10^{40}, for instance, is just the present value in the universe and increases as time increases. This proposal, however, can be experimentally tested and has been found false. (Though certain fringe groups still argue for it.)

2. Anthropic Cosmological Coincidences

Dirac and Eddington were just bothered by these numbers because they seemed like "design parameters." What they wanted was to show that the universe could not be any other way than it is, so that design would have nothing to do with the laws of physics.

Later scientists found that these large numbers are related to the existence of life. They found that life would be impossible given very small changes in the ratios. This is called an "anthropic" coincidence.

Since there is no reason from the theories themselves why the parameters have to have the observed values, one can calculate the probability of them having the "right" values for life by imagining an ensemble of many universes with varying parameters (this ensemble method is standard in physics.) Then one finds that the probability is extremely low. The following are some quotes from P.C.W. Davies, The Accidental Universe (Cambridge University Press, 1982):

"For a star to avoid convective instability, ... $\alpha_G \sim \alpha^{12}(m_e/m_p)^4$, where α is the electromagnetic fine structure constant. This remarkable relation compares the strength of gravity (on the left) with the strength of electromagnetism, and the ratio of the electron to proton mass.... Putting in the numbers, one obtains 5.9×10^{-39} for the left hand side and 2.0×10^{-39} for the right hand side. Nature has evidently picked the values of the fundamental constants in such a way that typical stars lie very close indeed to the boundary of convective instability. The fact that the two sides of [this relation] are such enormous numbers, and yet lie so close to each other, is truly astonishing. If gravity were *very* slightly weaker, or electromagnetism *very* slightly stronger, (or the electron slightly less massive relative to the proton), all stars would be red dwarfs. A correspondingly small change the other way, and they would all be blue giants. Carter has argued that a star's surface convection plays an important role in planetary formation, so that a world with slightly less gravity might have no planets. In either case, weaker or stronger, the nature of the universe would be radically different.
p. 73

"Present observations indicate that $0.01 < \rho/\rho_{crit} < 10$ so $(\rho - \rho_{crit})/\rho_{crit}$ lies anywhere between -1 and +9. This does not, perhaps, seem so remarkable. However, one must remember that ρ is time dependent....At the Planck time-- the earliest epoch at which we can have any confidence in the theory-- the ratio was at an almost infinitesimal 10^{-60}. If one regards the Planck time as the initial moment when the subsequent cosmic dynamics were determined, it is necessary to suppose that nature chose ρ to differ from ρ_{crit} by no more than one part on 10^{60}. We know of no physical reason why ρ is not a purely arbitrary number. Nature could apparently have chosen any value at all. To choose ρ so close to ρ_{crit}, fine-tuned to such stunning accuracy, is surely one of the great mysteries of cosmology. Had this delicate tuning of values been even slightly upset, the subsequent structure of the universe would have been totally different. If the crucial ratio had been 10^{-57} rather than $<10^{-60}$, the universe would not even exist, having collapsed into oblivion after just a few million years.
pp. 89-90

"The currently observed universe was causally divided into at least 10^{80} separate regions at the Planck epoch, yet as has been emphasized, the cosmos presents a remarkably uniform aspect....It is hard to resist the temptation of something-- some influence capable of transcending spacetime and causality-- possessing an overview of the entire cosmos at the instant of its creation, and manipulating all the causally disconnected parts to go bang with almost exactly the same vigour at the same time, and yet not so exactly coordinated as to preclude the small scale, slight irregularities that eventually formed the galaxies, and us.
pp. 94-95

"If G, or g_w [the weak force constant] , differed from their actual values by even one part in 10^{50}, the precise balance against Λ [the cosmological constant] would be drastically altered. Moreover, in the case of the so-called grand unified theories, the precision of the matching must be increased to better than one part in 10^{100}.
p. 107

"[Hoyle comments,] "If you wanted to produce carbon and oxygen in roughly equal quantities by stellar nucleosynthesis, these are the two levels you would have to fix, and your fixing would have to be just about where these levels are actually found to be.... A commonsense interpretation of the

facts suggests that a superintellect has monkeyed with physics, as well as chemistry and biology, and that there are no blind forces worth speaking about in nature."
p. 118

"Imagine a Creator equipped with a pin, blindly choosing one of the universes at random from among a vast collection of contenders. The chances of His picking a universe compatible with life as we know it is then exceedingly small. ...Accepting the world-ensemble concept enables one to assert the general fact that our world is indeed extremely unlikely on *a priori* grounds, and that we are immensely fortunate to exist, even if we cannot assert precisely *how* fortunate.
Many people of a religious persuasion will no doubt find support from these ideas for the belief that the Creator did not aim the cosmic pin at random, but did so with finely computed precision, with the express purpose that it *would* be suitable for habitation."
p. 123

The basic reason for the extremely low odds that Davies points out is that the cosmological equations are "stiff" equations. (Barrow and Tipler, in The Anthropic Cosmological Principle, pp. 408-412, give a good discussion of this.) Very small changes at the beginning are amplified enormously. For example, imagine trying to roll a ball down the edge of a knife. There is one initial condition which will lead to the ball rolling all the way down, but almost all initial conditions lead to the ball falling off on one side or the other. Getting the universe to hit the spot that allows life is like getting the ball to roll all the way down the knife.

In the past 15 years, many physicists have tried to eliminate this "stiffness" by noting that certain special cases of parameters are not stiff. One of these cases would be if the mass in the universe were about 10 times greater than actually observed. This led to the search for "Dark Matter." This theory has fallen into disfavor. Most scientists believe that Dark Matter exists, but only enough to give about 2-3 times the observed mass, which would still leave very stiff cosmological equations. One of the reasons for the lack of optimism is that recent observations seem to prove that there is a cosmological constant (a universal pressure causing the universe to expand) which takes the role of another "design parameter" which has a special value for no obvious reason.

3. Calculating odds of life within the existing universe

Another type of "large numbers paradox" takes the laws of nature as given, and asks what is the probability of life as we know it arising given those laws. For example, one can ask what is the likelihood of DNA which allows life? A simple "back of the envelope" or "order of magnitude" calculation goes as follows: (1) There are about 10^{80} baryons (normal particles like protons) in the universe. (2) There have been about 10^{18} seconds in the universe, that is, 10^{27} nanoseconds. (3) There are approximately 100,000 genes in human DNA, about 1000 nucleotides in a single gene, and about 100 baryons in a single nucleotide. (This is obviously a very crude estimate). (4) Suppose that all baryons in the universe form DNA, and every nanosecond they form a new combination of DNA. (I pick a nanosecond because to change DNA requires atomic motion, and atoms require at least a nanosecond to move appreciably.) Then in the age of the universe the maximum number of combinations tried is $(10^{80})(10^{27})/(10^{10}) = 10^{97}$. But the total number of DNA combinations is of order $4^{(100,000)(100)} = 10^{(6,000,000)}$. (This assumes only 100 "important" nucleotides per gene.) This is vastly larger than 10^{97}; in other words, a fraction less than $10^{-5,999,900}$ of all possible combinations of DNA can have been tried in all the age of the universe.

The following is a quote from Barrow and Tipler, The Anthropic Cosmological Principle, (Oxford University Press, 1988), p. 565, which gives a somewhat more concrete estimate:

"The odds for assembling a single gene are between $4^{-180} = 4 \times 10^{-109}$ and $4^{-360} = 1.8 \times 10^{-217}$. These numbers are so incredibly small that DeLey opines that an enzyme arises only once in during

evolution. ... There simply has not been sufficient time since the formation of the earth to try a number of nucleotide base combinations even remotely comparable to these numbers. The number of bacteria on Earth today is estimated to be of the order of 10^{27}; assuming a bacterial reproduction time of 1 hour, there have been at most 10^{40} bacteria in the entire past history of the Earth. With the order of 10^{7} nucleotide bases per bacterium, it would be possible to try some 10^{47} nucleotide combinations during the past, which is 52 orders of magnitude too few.

"The odds against assembling the human genome spontaneously is even more enormous: the probability of assembling it is between $(4^{180})^{110,000} = 10^{-12000000}$ and $(4^{360})^{110,000} = 10^{-24000000}$."

These low odds only apply if the construction of DNA is random. But that is what one must assume to get life started. Once life exists, the construction of DNA is not random, but we know of no reason why nonliving stuff if the universe should favor living over nonliving DNA.

If most combinations of DNA gave rise to life, then it would not matter that so few combinations have been tried. But everything we know about DNA tells us that the number of combinations which allow life is extremely small; errors of only one or two nucleotides can lead to enormous deformities and the death in a fertilized egg.

An alternate approach to calculating the odds is to start from the other direction, and ask what is the simplest possible self-reproducing automaton that could exist, and then ask how many different parts it must have. After all, one might imagine that life does not necessarily require carbon-based DNA; if one defines life as any type of self-reproducing automaton, then it could in principle be much simpler. What is the least number of parts such a self-reproducing automaton could have, i.e. the minimum amount of encoded information? One approach is to write a computer program which simulates a self-reproducing automaton and see how many bits of information it needs. R.C. Newman, in Perspectives on Science and Christian Faith **40**, 24 (1988), argues that the shortest such self-reproducing automaton requires 86 parts. Then one can ask how many baryons it takes to encode that information (at least 86?) and what the odds of those baryons coming together the right way is (on the order of one part in 86!, where the "!" stands for "factorial"), and one can see that even for such a simple case it still exceeds the limits of the age of the universe to have such a thing occur by simple chance (69! is already greater than 10^{97}).

4. Entropy/information arguments

A fourth type of argument is based on entropy/information considerations. Entropy is essentially a measure of the number of "equivalent states" in a system (more on "equivalent states" below.) Disordered systems have many equivalent states, while ordered systems have few equivalent states. The 2nd law of thermodynamics says that entropy always increases in a closed system.

A way of characterizing a designed system is to note that it has very few equivalent states. For example, a car or a computer can not tolerate random changes to its parts without enormous change in its function. (Try opening your computer and changing a few parts around to see this.)

We are not surprised by ice forming spontaneously, in which a system becomes more ordered, because the water can give up heat by radiation to the rest of the universe, which has a background temperature of 3 K. We would be very surprised by the spontaneous formation of a refrigerator, however. This is because a refrigerator has many fewer equivalent states than ice. Another way of putting this is that the "information content" in a refrigerator is much greater-- the more specified a system is, the fewer degrees of freedom and therefore the fewer equivalent states.

A human body has vastly more information than a refrigerator. It therefore seems to violate the Second Law to form life. It is not a violation of the Second Law for entropy to get lower in some local region, as long as the local entropy does not get lower than the average entropy of the universe. But a living being has much fewer equivalent states than the same number of atoms at the average entropy of the universe. The operation of a refrigerator does not violate the Second Law, but the spontaneous appearance of a refrigerator would.

Should we be surprised?

1. Statistics arguments

Some atheists have countered that the fact that life is improbably should not be surprising, because the universe had to be some way out of all the different possibilities, so why not this way? If I see a license plate "AFX 67J" should I be surprised at the unlikelihood that I saw that "exact" license plate and no other?

This gets us back to the foundations of statistical mechanics. The answer to this question was worked out in the late 1800's to most people's satisfaction. One can put it this way: suppose I throw a bunch of Scrabble letters on the floor. Why would the series "DAVIDSNOKELISTENUPGODEXISTS" be surprising, and "DSKXOSNGIINPOVDAELTENDESTSI" wouldn't be? Each exact series is equally likely.

Analogously, it is a possible configuration of the atoms in this room to line up along one wall, causing me to suffocate. That exact configuration is just as likely as the exact configuration of the atoms at this present instant. Why don't I worry about it then?

The answer is that the present configuration of atoms is one of a vast number of "equivalent states". What we mean is that they are equivalent as affecting me, the observer. If there was a Maxwell's Demon who could see all the different exact configurations of the atoms at all times, they would not be equivalent. This is why Maxwell's Demon does not violate the Second Law, because the system is already in a low entropy state-- to him.

In the case of the Scrabble throw, the first series is not equivalent to any other state, because it has special properties as relating to me, the observer. There are a vast number of possible configurations that would be "equivalent" to the second series, that is, meaningless to me.

In the same way, the existence of life is special to me, the observer. It is therefore reasonable to be surprised. I highly recommend the essay by John Leslie listed in the bibliography, which relates to this question. He gives the story of the man who was fired at by 100 sharpshooters in a firing squad, who lives because all 100 sharpshooters miss. Should he be surprised, or should he say "There was a small probability that any given shooter would miss, and an even smaller probability that all would miss, but that possibility is just one of many equally likely outcomes, and I shouldn't be surprised, because if they hadn't missed, I wouldn't be here to talk about it." Or is it reasonable for him to surmise that purpose and intent had something to do with the outcome?

2. The example of the "improbable" shape of the sun.

Suppose I constructed a bad argument for design. I suppose that the circular shape of the sun is one of many possible shapes. What is the likelihood of it being as close to exactly circular as it is? I could imagine an ensemble of all possible shapes (various ovals, squares, etc.), and calculate that the odds of it falling into a circular shape are extremely low.

Why would this be silly? It is because the shape of the sun is not random; there is a force of gravity which gives it its shape. This points out a general rule: extreme improbabilities based on the assumption of uncorrelated causes means that mean the causes are not uncorrelated. The distance of one part of the sun above the center is not uncorrelated to the distance of another part-- they are both affected by the same law of gravity.

In the same way, if I came into a room and saw a bunch of Scrabble letters spelling out my name, I would conclude that the placement of the letters was not uncorrelated, but instead that there was a single cause (someone put them that way.)

Likewise, the extreme improbabilities associated with the existence of life based on cosmology lead us to expect that there is a unifying cause. This might be Design or something else, but it will just not do to say that the improbabilities should not surprise us, that there is no reason to look for any other cause than uncorrelated randomness.

Atheistic counterarguments

The above facts are generally agreed upon. Here I survey some of the atheistic approaches to dealing with them.

1. Holding out for a new law of nature

A person might look at the example of the shape of the sun, above, and argue that evolution is in the state right now of a person looking at the shape of the sun with no knowledge of gravity. Once the theory of gravity comes along, the mystery goes away. How do we know that some new law won't come along that explains everything easily?

Of course, no one can prove that such won't happen, since no one can predict the future, but does history give us reason to expect that? There is a common legend, which I call the "legend of the God of the gaps" which says that throughout history, theists have been seeing evidence for God's existence in various "gaps of explanation" of science, which science then comes along and fills, leaving ever less room for God. The improbabilities mentioned above are just a few remaining gaps which ought not concern us.

Is the way history has really gone? What evidences of design have been adequately explained away by science? No Christians ever used the shape of the sun to argue for the existence of God. They have used the same subject-- the design of life-- which is before us today.

To illustrate this, let me tell two stories. In the 19th century, two gaps caused problems for Darwinists. First, they had no explanation for the mechanism of transmission of traits from one generation to the next. Second, they had no answer to Lord Kelvin's argument that the earth could not be old enough to allow random variations to produce all the apparent design we see, because simple physical arguments showed the sun could not burn for millions of years.

In the middle of this century, two scientific breakthroughs occurred which seemed to solve these problems. Watson and Crick discovered DNA, and the nuclear theory of Bethe showed that stars could burn for millions of years using nuclear fusion. These apparently filled the gaps with resounding success. Yet within twenty years, both discoveries had raised as many problems as they had solved. The information stored in DNA is vast, and no one today has an adequate explanation for how this highly complicated molecule arose out of mud and water. Not only appearance of the molecule, but the appearance of the mechanism of readout of the information, the appearance of methods of replication of the information without error, and appearance of the delicate balance of repair and maintenance of the molecular systems using the

information stored in DNA have no adequate explanation within chemical evolutionary theory today.

On the second question, the nuclear theory of Bethe showed that stars could burn for millions of years, consistent with the geological record. Yet this nuclear theory has strong implications for cosmology. Many scientists, starting in the 1960's only a few years after Bethe's work, showed that in order for the stars to burn as long as they do, certain exquisite balances must exist in the fundamental constants of the universe, the now-famous large numbers coincidences we have been discussing.

At this point, holding out for a new law of nature is just bare faith. It could be that one will be discovered, but I don't worry much about it. Behe's book, Darwin's Black Box, takes its title from the fact that over the years, elements of life have been taken as "black boxes" in which one could hide the hoped-for new law of nature which would explain all the improbabilities. As technology has progressed, more and more boxes have been opened, until now the last box has been opened-- all of the elements of life are now known in terms of their constituent atoms, and we understand atoms. There are few places to hide a new law of nature any more.

Some people have proposed a law of "self-organization" in nature. They are essentially arguing by analogy-- we see some things that clump together, such as sand, and from this we can generalize that DNA molecules should self-organize in the same way. Computer programs are offered which attempt to demonstrate this. I have been so far unimpressed with the analogy. For example, much was made of the way in which fractals can generate pictures that look like trees or landscapes. But fractals imitate only the most gross features of a tree, namely branching. Can they give blossoms that bloom in the spring, birds' nests in the branches, a system of molecules that converts light into sugar with near-perfect efficiency, etc.? The analogy of self-organization models seems to me like a child who puts two blocks on each other, then looks at a skyscraper and says, "It is just the same thing, not very impressive at all."

2. Many worlds

Many atheists have conceded that the search for a new force of nature which will explain all these coincidences is unlikely, and so another hypothesis has gained favor. This is the Many Worlds hypothesis. There are two versions: either a Wheeler-Everitt quantum mechanical many-worlds model of "parallel universes," or a tweaking of the Standard Model of cosmology (e.g. Inflation) which would allow our universe to exist as a sub-universe of a greater macro-universe. In this view, the anthropic coincidences are just the same as Queen Elizabeth asking "What are the odds of me being born Queen of England?" Someone had to be.

The a Wheeler-Everitt quantum mechanical many-worlds model is not believed by most physicists. It raises as many problems as it solves, such as the apparent infinite violation of energy conservation which occurs when the universe is split in two at every quantum event, why the arrow of time occurs in this model, how parts of the universe very distant from us can split into two when something occurs here, etc.

The tweaking of the Standard Model suffers from the problem that the Standard Model is a very well-tested and successful theory that does not stand a lot of tweaking. It is one of the best-tested theories in history, and any new theory must still successfully fit all the data which the Standard Model fits.

Both postulates suffer from the fact that we have no evidence of even one other universe, much less an infinity of them. It is an infinite violation of Occam's Razor, by postulating an infinite number of unobservable entities, each of which is an entire universe.

3. Neo-paganism

Another view is an explicitly spiritual but non-Christian belief in a "life force" or "emerging design." This view is connected with Tielhard de Chardin, and popularized by Louise Young. There is no "life force" measurable by science, but this New-Agey view sees it as existing in a spiritual plane.

4. The argument from Silence

Some people don't postulate anything, but just fall back on this stopper: this all sounds fine, but if I was God, I would be more clear in making myself known! (Or, I wouldn't run the universe the way it is.)

This has emotional weight with me, but as I look at it, it carries no logical weight. Sure, I would like God to speak more clearly or do things differently. But who am I to tell God what to do? He is God and can do anything He wants. I can see so reason why it should be logically impossible for God to make us and then hide completely, or snuff us out without telling us why.

At the same time, is God really silent? Perhaps we are so used to seeing Him we "can't see the forest for the trees." Many people, including myself, feel very deep spiritual feelings when experiencing nature. I identify this with God, and others do not, but we seem to agree that there is something deep going on. So I end where I began, with , "I think that I shall never see, a thing as lovely as a tree."

<u>Questions</u>

1. One may agree that there are fantastic coincidences that lead to the existence of life. But if God exists, wouldn't that mean there are fantastic coincidences lead to the existence of God? Why is "God" a better place to stop than life?

The debate is really about the nature of the fundamental ground of the universe. Everyone has to agree that there is something which is fundamental, because it is illogical to have a universe in which everything is contingent. The theist says that the fundamental ground of the universe has the attributes of Purpose. The atheist says there is no purpose, and that the design we see is just due to uncorrelated random forces.

It is a good approach to ask why in the case of the shape of the sun, most people are willing to stop with the explanation of "gravity" and not ask "but where did gravity come from?" Of course, one can ask that, but gravity eliminates the lack of correlation, putting many things (the distance of various parts of the sun from the center) into one thing (gravity). Therefore it is a satisfying explanation of the shape of the sun, if not for everything there is. In the same way, believing in God is saying that the many elements of design in the universe are connected by a purpose or intent. It is an adequate explanation for the apparent design, though perhaps not the explanation to every question one would ever like to ask.

There is nothing illogical in positing that God has no beginning. There is nothing illogical about an uncaused Cause, which can be as complex as you like.

2. Does belief in God as designer mean an end to scientific inquiry? For example, in the case of the shape of the sun, suppose a believer said "It is round because God made it that way." That might be true but would not be useful science.

If you are an electronics manufacturer, and someone gives you a chip and says "This is the latest design by Intel," does that make you more or less interested in looking into the details of that

chip? In my experience, most people, when given an example of exquisite design, are very interested in "reverse engineering" to figure out the design (I have a friend at AMD who does this.) On the other hand, if someone said, "This is a random piece of silicon from the junk heap" you would be less interested.

Historically, science was started in Europe by Christians who believed in design, who wanted to "reverse engineer" the universe to "think God's thoughts after Him." They wanted to see how He did it, with the expectation that it would lead to useful knowledge. Even today, I am always amused to hear people talk about how they learn things from biological systems on the assumption that "Nature" has "perfectly designed" its systems. They are not giving credit to God, but they are operating on the assumption of design anyway.

Of course, some people are just not curious, and saying "God just did it" is good enough for them. But the same type of people of the non-Christian sort often just say "Evolution did it" or "Chemistry did it" without being very curious either.

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