

## **LECTURES #11, 12: Do Anthropic Coincidences Require Explanation?**

Robert C. Koons

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#### **What are the Coincidences?**

The existence of "anthropic coincidences" was first discovered in the early 1970's by cosmologist Branden Carter. Since that time, the list of coincidences has grown dramatically. An anthropic coincidence consists of some feature of the laws of nature, the fundamental constituents of matter, or the initial condition of the universe that had to take a value within some interval in order for life (and hence, for human observers) to exist at all. These coincidences can be grouped into several categories: (i) features of the fundamental laws of nature, including the relative strengths of fundamental forces and other physical constants, (ii) characteristics of the fundamental particles of matter, (iii) the size, degree of flatness and smoothness, and rate of expansion of matter emerging from the big bang. and (iv) features of the solar system and of the earth. (The fourth category could be considered a separate sort of coincidence, since it refers to unlikelihood of even one planet as suited for life as is the earth to come into being. Unlike the other coincidences, it does not refer to universal features of the cosmos.)

If any of these features of the universe had lied outside a narrow interval of values, then the existence of any sort of complex chemistry would have been impossible. Complex, self-replicating life seems to depend on the co-existence of a combination of lighter and heavier elements, including such elements as hydrogen, oxygen and carbon. Furthermore, life seems to depend on the formation of stars and planetary systems, since no life could exist in the fridity of starless deep space or within the superheated interiors of stars. These conditions are interconnected, since only if stars can form and later become supernovas can any of

the heavier elements be formed. These processes of star formation and destruction turn out to be very sensitive to the slightest variations in the fundamental constants of the universe. Consequently, the universe is in some sense "fine-tuned" for the possibility of complex chemistry and thus of life.

In most cases, the degree of sensitivity can be quantified precisely. This quantifiable degree of fine-tuning is an absolute, measure-independent quantity. In some cases, the degree of sensitivity is almost unimaginably high. For instance, if the ratio of the electromagnetic force to the gravitational force were changed by one part in 10 to the 40th power, star formation would have been impossible. Similarly, the ratio of the total number of electrons to the total number of protons could not vary by more than one in 10 to the 37th power, without disastrous implications for galaxy and star formation.

How surprising are these coincidences? This depends on what philosophers call your prior probabilities. If I knew nothing about the ratio of electromagnetic force to gravitational force, and if I knew nothing about the importance of this ratio to life, I would certainly assign a very low prior probability to that ratio's lying within an interval that is no wider than one part in 10 to the 40th power. Thus, discovering both that there is such an interval defining the conditions of life, and that the actual value does lie within that interval, is to discover something that would be very surprising to any reasonable investigator. These surprising discovery seems to call for some explanation.

We will consider two possible explanations of the coincidences: theism, and the ensemble of universes/observer selection hypothesis. According to theism, the cause of the universe is an intelligent and purposeful agent who had the eventual existence of life as a purpose and end, and who intentionally set the values of the fundamental constants so as to realize that purpose. According to the ensemble-of-universes hypothesis, there are an astronomically large number of universes, each on the scale of the observable universe. In each of these universes, the fundamental constants take values at random. Since there are so many of them, chance alone is able to ensure that (with a high degree of probability) at least one of them will be life-permitting. It is not surprising that we find ourselves in one of these universes, since observers like us could not exist in any other kind.

In two weeks, we will consider the question of which of these two hypotheses provides the best explanation for the anthropic coincidences. For now, I would like to turn to six objections that have been made to the claim that it is desirable, or even possible, to explain the anthropic coincidences.

### **Objection #1: The Problem of Old Evidence**

We already know that life exists, and, consequently, we know that whatever is physically required for life to exist must be actual. Any hypothesis that purports to "explain" the coincidences is explaining something we already know to be true. It is not thereby making a risky prediction that may or may not be borne out by subsequent observation. Hypotheses can be confirmed or made more probable only when they make such risky predictions, as when Halley predicted the return of Halley's comet, or Einstein predicted the bending of light by the sun's gravity.

This objection can be illustrated by using Bayes's theorem, a basic theorem of probability theory. Bayesians stipulate that the posterior probability of a hypothesis, after observing result E, is equal to  $P(H/E)$ . According to Bayes's theorem,  $P(H/E)$  is equal to the product of  $P(H)$ , the prior probability of H, and  $P(E/H)$ , the degree to which H made E probable, divided by  $P(E)$ , the prior probability of E. The probability of H is increased if two conditions are met: (i)  $P(H)$  is not zero, (ii)  $P(E/H)$  is greater than  $P(E)$ . If E is not a prediction, then we already know E to be true. In this case,  $P(E)$  is 1, and  $P(E/H)$  cannot be greater than  $P(E)$ . This means that no hypothesis can be confirmed by E. This implication of Bayes's theorem is called "the problem of old evidence".

Most philosophers of science believe that this apparent implication of Bayesian theory should not be accepted. There are many cases in the history of science in which a theory was accepted on the basis of its ability to explain, in a very simple way, a wide range of previously-known data. For instance, Copernicus's

theory was accepted entirely on the basis of its providing a simpler, more economical explanation of astronomical data that had been known for hundreds, or even thousands of years. According to the strict Bayesian account, this data should have provided no support whatsoever to Copernicus's theory -- an incredible result.

The standard solution to the problem goes something like this. Instead of using the actual probability of the data,  $E$ , in using Bayes's theorem, we instead use a hypothetical probability value, one representing how likely we would have found  $E$  to be, had we never actually observed it. Thus, the astronomical data we have observed for many thousands of years could receive a very low hypothetical probability, representing how unlikely these observations would have been to one unfamiliar with them.

Applying this solution to the case of the anthropic coincidences, we would have to assign some hypothetical probability to the anthropic coincidences. Given the narrowness of the required intervals, how surprising is it that life actually came into being? The answer would seem to be, very unlikely (unless there are a large number of actual universes within which life could arise by chance).

John Leslie illustrates this point by means of the Firing Squad analogy on pages 13 and 14. Imagine that you are facing a firing squad of sharpshooters, firing at close range. Somehow, you survive the volley. Is the volley something that requires an explanation? It is old evidence -- you already know with probability 1 that you are still alive. Nonetheless, it is, from a suitably impersonal perspective, a very surprising thing that you did survive, under the circumstances. Similarly, we already know, with probability 1, that life exists, but this is a very surprising fact, given the anthropic coincidences that were required.

### **Laws of Nature Cannot Be Explained**

Some have objected that the anthropic coincidences cannot be explained, since they involve the fundamental laws of nature. The laws of nature are used in explaining other things -- they themselves cannot be explained. They are rock-bottom, matters of physical necessity, immutable and uncaused. This objection is sometimes based on actual scientific practice -- scientists seek to discover the laws of nature and to use these laws in constructing explanations of phenomena. They do not try to explain the laws of nature themselves.

There are several points to make in response to this. First, it is no longer true that scientists never seek to explain the laws of nature. Much of recent cosmology and unified force theory has attempted to do that. Second, even if scientists never did attempt to explain the fundamental laws, it would still be an open question whether they should do so. Finally, whether something can or should be explained is itself an empirical matter, to be decided on a case by case basis, and not on the basis of dogmatic, a priori pronouncements. The anthropic coincidences are themselves excellent evidence that the laws of nature can and should be explained. If the laws really were absolute rock bottom, inexplicable brute facts, then we would be faced with a set of inexplicable coincidences. If the only price we have to pay in order to explain these coincidences is to revise our beliefs about the rock-bottom status of physical laws, this is a small price to pay.

There is an episode near the end of Carl Sagan's novel, *Contact*, that illustrates this point. A mathematician discovers, hidden in the apparently random sequence of numbers in the binary expansion of  $\pi$ , an encrypted, three-dimensional hologram of the cosmos. The further the binary expansion is carried out, the sharper is the resolution of the hologram. Further, the hologram gives absolutely accurate information about the relative positions of galaxies and galaxy clusters, leading to new discoveries about the cosmos. In light of this discovery, the only possible conclusion to draw is that the number  $\pi$  is an artefact, created by some unfathomable intellect, who encoded it with this astronomical information. In advance of this remarkable discovery, no one would have thought of the value of  $\pi$  as something that could be explained in terms of anything else. It seems like a mathematical brute fact, rock bottom if anything is. However, this conviction is subject to change in the light of new information. Similarly, the discovery of the anthropic

coincidences should lead us to revise our prior conviction that the fundamental laws and constants of the universe could not be explained.

### **Something Had to Happen -- The Problem of Specification**

Stephen Jay Gould, among others, has offered this objection. It is true that the anthropic settings of the physical constants is antecedently very unlikely. However, whatever value these constants had taken would also have been, from one point of view or another, extremely unlikely. Unlikely things happen all the time. Every time a hand of poker is dealt out, the exact constitution of the hands involved is extremely unlikely. The exact position of the molecules in this room at the present time is an astronomically unlikely arrangement.

This objection raises a fundamental problem of statistical inference: the problem of specification. If every outcome is equally unlikely, how is it that at some times we are able to exclude chance as an explanation, instead preferring the hypothesizing of some causal mechanism?

The general answer to this problem would seem to go something like this. A result is specified when it conforms to a very simple pattern, a pattern that can be specified by a simple rule or algorithm. The simpler the rule or pattern, the greater the degree of specification. When a result is very likely and very specified, no explanation is called for. For instance, if I hope that I will get a red card on the next draw, and I do get one, no special explanation is called for. Even though the result was highly specified, it was also highly likely, since I had a 50/50 chance of drawing a red card. When a result is very unlikely but has a low degree of specification, once again, no explanation is needed. If I draw a 2 of hearts, queen of spades, 5 of diamonds, 10 of clubs and 7 of spades, then this particular hand is very unlikely, but it is also relatively unspecified, since it takes quite a bit of information to spell out this particular result. If I were to spell out in equal detail 7 different hands, each fairly undistinguished, then the event of being dealt these 7 hands, in one particular order, is astronomically unlikely, but also highly unspecified.

In contrast, suppose I am dealt a royal flush (a straight flush, ace high) seven times in a row. This is an astronomically unlikely result, and, in the context of a game of poker, also a highly specified result. It conforms to a very simple pattern: being dealt the very best hand seven times in a row. Such an outcome demands an explanation (some sort of non-random shuffling and dealing).

The anthropic coincidences are extremely unlikely. Are they also highly specified? It would seem that they are. They all fall into one simple pattern: conditions necessary for the existence of complex, molecular chemistry. If the realization of this pattern can be explained, it should be.

One might object that the pattern is in fact a very complex one, since life and organic chemistry are themselves very complex. This objection would be based on a confusion. Life is very simple in its specification (something like "self-replication carbon-based chemical systems"), but it is always very complex in its realization. The simplest forms of life that we know about have hundreds of thousands of interdependent parts, each consisting of long chains of amino or nucleic acids. It is this complexity of realization that makes life such an unlikely state for matter to be in. But the complexity of realization does not contradict the fact that the specification of life is quite simple. For example, suppose that my four-year-old son sorts 100 pictures into two piles, one a pile of pictures of living things, and the other a pile of pictures of inanimate objects. The living/non-living pattern is extremely simple, so the result is highly specified, even if each individual picture is highly complex.

### **The Possibility of Exotic Life**

Some have objected that the anthropic coincidences involve a simple failure of imagination. We can see that life like ours, based on carbon molecules, in a universe like ours, organized around stars and galaxies, would be impossible if any of the anthropic coincidences had failed to be realized. However, this may

simply overlook the possibility of very exotic life, based on radically different kinds of chemistry and physics, in very exotic universes.

First, it is not at all clear that the anthropic coincidences are really vulnerable to this charge. In many cases, it seems clear that, in the absence of the anthropic coincidences, the universe would have been so short-lived, or so lacking in interesting structure or heterogeneity, that nothing approximating the complexities of life could be possible.

In any case, even if the charge were entirely just, there still remains a remarkable coincidence in need of explanation. All we need to do is to complicate the specification of the event to be explained very slightly. What we need to explain is this: the coincidence of factors necessary for the existence of complex, carbon-based molecules. In so doing, we are trying to explain the coincidences needed to make life like ours possible. The possible existence of exotic life is simply irrelevant to this problem. Whether or not such life is possible, we still are faced with a very unlikely and very specified event. The universe appears to be fine-tuned, not just to make life possible, but to make carbon-based life possible.

John Leslie gives another good illustration of this fact, the story of the Fly on the Wall. Suppose we have a long stone wall. In places, the wall is entirely covered by flies. However, there is one long stretch of the wall, several hundred yards long, on which a solitary fly (and nothing else of any interest) is resting. Call this stretch the alpha segment of the wall. Suddenly, a gunshot rings out, and the solitary fly is shot. In this case, we have an event that is very unlikely (the hitting of one particular point on the alpha segment) and very specified (the hitting of a fly-occupied spot). This event calls for some sort of explanation, even though the hitting of a fly somewhere on the wall would not require an explanation, since the event of hitting-a-fly-somewhere-on-the-wall is not at all unlikely, given the presence of fly-infested stretches of the wall.

Similarly, if exotic life is in fact possible, then we do not need an explanation for the existence of life. We do, however, need an explanation of the existence of carbon-based life, since this is both highly unlikely and highly specified.

### **Principle of Mediocrity & the Rejection of Anthropocentricity**

The principle of mediocrity is a rule-of-thumb for the conduct of science. It requires that we assume that we, and our particular location in space and time, are nothing special. We must assume that what we can observe in our own immediate neighborhood is typical of what is and what could be universally. Something like the principle of mediocrity is presupposed whenever we indulge in generalization: whenever we infer that a law of nature exists because we do not observe any violations. If we did not assume that our own space-time neighborhood is typical of the entire universe, then any generalization of our observations would be illegitimate.

The principle of mediocrity might be applied to the anthropic coincidences in the following way. We might say that the principle of mediocrity requires us to assume that all possible universes are very much like the actual universe. Since the actual universe is life-permitting, almost all possible universes must be so. But if almost all possible universes are life-permitting, then that is by itself a sufficient explanation of the anthropic coincidences.

There are at least two problems with this argument. First, the narrowness of the intervals involved (as narrow as one part in 10 to the 40th power) make it very unlikely that almost all possible universes have values that lie within the required intervals. The principle of mediocrity is a reasonable thing to presume at the beginning of our investigations, but when we discover overwhelming evidence that our own universe is very special, this evidence should override the apriori rule of thumb. Second, even if it were true that almost all possible universes are life-permitting, this does not rule out the need for an explanation of this fact. In fact, a theistic explanation would preserve the principle of mediocrity, since a theist will hold that typical universes are life-permitting, since in most cases, God would design the universe to be so.

Another closely related principle of scientific inquiry is the rejection of anthropocentricity. This principle has become firmly engrained in scientific practice ever since the heliocentric model replaced the geocentric model. The point of the principle is to guard against a very common human bias -- that of assuming that we are more important than we are. It is natural for us to assume that we are the center around which everything else revolves, and it is essential to the acquisition of objective, scientific knowledge that we fight against this bias. The anthropic coincidences put the existence of human beings into the cosmic driver's seat, in violation of this principle.

Again, there are a couple of things to be said in response. First, the "anthropic" coincidences are not well-named. They should really be called the biotropic or the carbobic principle, since they concern the possibility of the existence of life, or at least, of carbon-based, planetary life. This does not put the species homo sapiens into any special place in the grand scheme of things. It does not necessarily make the planet earth the center of the universe, since there may, for all we know, be many planets equally well-crafted for the existence of life.

Second, even if the anthropic coincidences do lead us to reject, or at least to modify, the principle of non-anthropocentricity, this seems the reasonable thing to do in light of the actual data. Once again, we cannot let apriori legislation determine in advance how we must respond to any possible data. If we find overwhelming evidence that the cosmos has been fashioned for the sake of life on earth, then we should accept this conclusion. At most, the principle of non-anthropocentricity should make us cautious about jumping too soon to such a conclusion.

### **Too Small a Sample Size -- Only One Universe**

This objection is one first pressed by David Hume. Hume argues that we cannot draw any conclusions about the causes of a thing until we have observed many tokens of the same type. I can conclude that this egg was probably laid by a chicken only on the basis of many observations of chickens laying eggs in the past. Since we can observe only one universe, we cannot possibly be in a position to draw any conclusions about what sort of thing may have caused it.

Right away, we should concede that our situation is not an optimal one. If we could somehow observe 30 or 50 universes, each on the scale of our own, each taking very different sets of values for the fundamental constants, and yet each being structured so as to make life possible, then we would be in an optimal position to draw the conclusion that some kind of creator or designer has been at work. The question remains, however, just how far from optimal is our actual situation?

If we had to rely on only one feature of the universe, or on only two or three, we might well be in a position that warranted extreme caution. We might be wrong in our estimations of the degree of sensitivity of life to small changes in one or two parameters. However, when we have twenty-five or more features of the universe, each of which appears to be highly constrained, the basis for an inference to an appropriate explanation is much stronger.

I cannot see any basis for an absolute prohibition on reasoning from single cases. In science, history and forensics, we do sometimes come up against unique sets of circumstances. We have observed, for example, only two cases of the use of an atomic bomb against a city. Even if the bomb had been used only once, it surely would have been possible for us to attribute the death and destruction to the use of the A-bomb. Everything pointed to the activity of a fireball of intense heat, originating from a single point. Similarly, we see many signs of the activity of some agency capable of fine-tuning the features of the universe for the sake of the existence of life.

Once again, John Leslie offers a parable in support of this response, the case of the Telepathic Painting (page 18). We are to imagine an experiment in which a purported telepath tries to duplicate a painting being produced simultaneously by another person halfway across the world. When the experiment is concluded, the two paintings are compared and found to be identical, stroke-for-stroke. Each painting contains

hundreds of details, exactly duplicated in the other. In such a case, we might not accept telepathy as the explanation for the coincidence, but we would surely expect to find some explanation. The fact that we are dealing only with a single case is surely irrelevant. The single case provides by itself enough data to warrant the search for an explanation.

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