Anthropic Coincidences

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How important is the human race in the scheme of things? According to the Epistle to Diognetus, a Christian work of the early second century, "God loved the race of men. It was for their sakes that He made the world." The consensus of later Christian tradition does not go quite that far, holding that the purpose of Creation is to manifest God's glory, not simply to benefit mankind. And yet Scripture and tradition certainly concur in teaching that the human race has a central place in the divine plan. In the Book of Genesis, the six days of creation culminate in the creation of man, and man alone of all the creatures is said to be made "in the image of God." If we are not the sole or the chief end of Creation, it is nevertheless the Jewish and Christian view that in creating the world God had the human race in mind. Indeed, St. Paul tells the Ephesians that they were chosen by God and destined to be His sons "before the foundation of the world."

On the other hand, we have often been told, science regards man and his place in the world very differently. In the story of science as it is told by materialists the human race is not central to the purpose of the universe for the simple reason that the universe has no purpose. This is the view set forth in a well–known passage in Steven Weinberg's best–selling book *The First Three Minutes*:

> It is almost irresistible for humans to believe that we have some special relation to the universe, that human life is not just a farcical outcome of a chain of accidents . . . but that we were somehow built–in from the beginning. . . . It is very hard for us to realize that [the entire earth] is just a tiny part of an overwhelmingly hostile universe. . . . The more the universe seems comprehensible, the more it also seems pointless.

It is the view not only of Weinberg but of many scientists that the progress of science has more and more made the universe appear "pointless," and the human race an accidental by–product of blind material forces. Indeed, this is thought by many to be the key lesson that science has to teach us. A particularly forthright champion of this view is the zoologist Richard Dawkins, who writes that "the universe we observe has precisely the properties we should expect if there is at bottom no design, no purpose, no evil, no good, nothing but pointless indifference."

The pointlessness of the cosmos and its indifference to human beings is also a main theme in the writings of the zoologist Stephen Jay Gould, who claims that the human race is a freak accident of evolutionary history, merely "a tiny twig on an ancient tree of life." We are, said Bertrand Russell, but "a curious accident in a backwater" of the universe.

Certainly, much in the history of science encourages this "marginalization of man." If nothing else, the very size of the cosmos seems to tell of our insignificance. And yet, discussions about the size and age of the universe do not come to grips with the real question: Is the human race an accident, or were we meant to be here? To put it in Weinberg's terms, were we "somehow built–in from the beginning?"

As it happens, new light has been shed on this question by the discoveries of modern physics. It has been noticed, especially since the work of the astrophysicist Brandon Carter in the 1970s, that there are many features of the laws of nature that seem arranged, even “fine–tuned,” to make possible the existence of life, including intelligent beings such as ourselves. At least on the face of it, these so–called “anthropic coincidences” would appear to support the idea that we *were* built–in from the beginning. Even some former atheists and agnostics have seen in them impressive evidence of a divine plan. And yet, many others maintain that a perfectly naturalistic explanation of these coincidences is possible. Rather than settling the age–old questions, then, the “anthropic” arguments seem only to have generated new controversy. Before getting into that controversy, it will be helpful to look at a few examples of anthropic coincidences. I will start with a detailed look at two of the most famous examples, both of which concern the origin of the chemical elements needed for life.

All life is based on chemistry—very complex chemistry, as even a cursory look at a biochemistry textbook makes clear. The human body, for instance, is made up of no fewer than twenty–five different chemical elements. Altogether, almost a hundred chemical elements occur naturally, the smallest being hydrogen, and the largest uranium. Where did all these elements come from? And why are the chemical possibilities of our universe so rich?

Hydrogen has been around since very soon after the Big Bang. But almost all of the other elements were forged later, either in the deep interiors of stars, or in the violent explosions called supernovas with which some stars end their lives. These supernova explosions are also important for life because they spew the elements made within stars out into space where they can form new stars, or planets, or people. Indeed, most of the elements in our bodies were made inside stars that exploded before the sun was born. We are quite literally made of stardust.

For our purposes, it is crucial to note that the elements are formed in a sequential manner by nuclear reactions in which the nuclei of smaller atoms fuse together to make the nuclei of larger atoms. These same “nuclear fusion” reactions also produce the energy radiated by stars (including, of course, the sun), energy that is essential to support life. The first step in the process of forging the elements is the fusing together of pairs of hydrogen nuclei to make something called “deuterium.” Deuterium is the first and vital link in the whole chain. If deuterium had been prevented from forming, none of the later steps could have taken place, and the universe would have contained no elements other than hydrogen. This would have been a disaster, for it is scarcely conceivable that a living thing could be made of hydrogen alone. Moreover, had the deuterium link been cut, the nuclear processes by which stars burn would have been prevented.

Everything thus depends on hydrogen being able to fuse to make deuterium. Here is where the first remarkable anthropic coincidence comes in. The force of nature that cements nuclei together is called the “strong nuclear force.” Had the strong nuclear force been weaker by even as little as 10 percent, it would not have been able to fuse two hydrogens together to make deuterium, and the prospects of life would have been dim indeed. But this is only the half of it. Had the strong nuclear force been only a few percent *stronger* than it is, an opposite disaster would have occurred. It would have been *too easy* for hydrogen nuclei to fuse together. The nuclear burning in stars would have gone much too fast. Stars would have burned themselves out in millions of years or less, rather than the several billion years that stars like the sun last. However, the history of life on earth suggests that billions of years are required for the evolution of complex life such as ourselves. The upshot of all these considerations is that the strong nuclear force has just the right strength: a little stronger or weaker and we would not have been here.

Once deuterium is made, deuterium nuclei can combine by fusion processes to make helium nuclei. These steps happen very readily. At this point, however, another critical juncture is reached: somehow, helium nuclei must fuse to make yet larger elements. But all the obvious ways this could happen are forbidden by the laws of physics. In particular, two helium nuclei cannot fuse together. This was quite a puzzle for nuclear theorists and astrophysicists. How did all the elements larger than helium come to be made?

The answer was found by Fred Hoyle, who suggested that nature in effect did a large double step to get past the missing rung in the ladder. When two helium nuclei collide in the interior of a star they cannot fuse permanently, but they do remain stuck together momentarily—for about a hundredth of a millionth of a billionth of a second. In that tiny sliver of time a third helium nucleus comes along and hits the other two in a three–way collision. *Three* heliums, as it happens, *do* have enough sticking power to fuse together permanently. When they do so they form a nucleus called "carbon–12." This highly unusual triple collision process is called the "three–alpha process," and it is the way that almost all of the carbon in the universe is made. Without it, the only elements around would be hydrogen and helium, leading to an almost certainly lifeless universe.

It was in looking closely at the three–alpha process that Hoyle discovered one of the most dramatic of the anthropic coincidences. Hoyle's preliminary calculations showed him that such a rare event as the three–alpha process would not make enough carbon unless something greatly enhanced its effectiveness. That something, he realized, must be what is called in physics a "resonance." There are many examples of resonance phenomena in everyday life. A big truck going by a house can rattle the window panes if the frequency of the sound waves matches up, or "resonates," with one of the "natural modes of vibration" of the window. Similarly, opera singers can shatter wine glasses by hitting just the right note. In other words, an effect that would ordinarily be very feeble can be greatly enhanced if it occurs resonantly.

Now, it happens that atomic nuclei too have characteristic "notes" or "modes of vibration," called "energy levels," and nuclear reactions can be enormously facilitated if they hit upon one of these energy levels. Hoyle pointed out that the three–alpha process could have produced enough carbon only if the carbon–12 nucleus has an energy level in just the right place. Indeed, experiments done shortly thereafter confirmed that it does. Had this energy level of carbon–12 been only a few percent higher or lower in frequency, the three–alpha process would have been out of tune, as it were. Without carbon, and the elements heavier than carbon, life as we know it would have been unable to exist.

One sees that the making of the chemical elements needed for life was, to borrow the Duke of Wellington's comment on his victory at Waterloo, "a damn close run thing."

One can see anthropic coincidences not only in the nuclear processes that formed the elements, but in many quite various aspects of the laws of physics. To give a better idea of this variety, I will describe a few more examples, though in less detail.

The "strong nuclear force" is one of four basic forces of nature that is presently known. The others are the so–called "weak interaction," gravity, and electromagnetism. In the phenomena of our everyday lives, electromagnetism plays a dominant, although perhaps not obvious, role. For example, matter is held together by the electrical attraction of atoms, and light consists of electromagnetic waves. In contrast, the strong nuclear force plays no direct role in effects that we can experience. That is because its influence extends only over subatomic distances. Nevertheless, the electromagnetic force is intrinsically much weaker than the strong nuclear force. In fact it is, in a certain well–defined sense, about one hundred times weaker. This is very fortunate. Had the electromagnetic force *not* been intrinsically much weaker than the strong nuclear force, the electrical energy packed inside a hydrogen nucleus would have been so great as to render it unstable. The "weak interaction" would then have made all the hydrogen in the world decay radioactively, with a very short half–life, into other particles. The world would have been left devoid of hydrogen, and therefore almost certainly of life. For water, which is indispensable for life, contains hydrogen, as do almost all organic molecules. We see, then, how life depends on a delicate balance among the various fundamental forces of nature, and in particular on the relative feebleness of electromagnetic effects.

Another fortunate fact has to do with the flatness of space. Einstein taught us that space–time is not flat, but curved. Because of this curvature, bodies seem to attract each other by the force we call gravity. However, it turns out that the space of our universe, if looked at on large enough scales of distance, is on average astonishingly flat. The "spatial curvature," as it is called, is very small. In fact, shortly after the Big Bang the spatial curvature of the universe was, to the accuracy of many decimal places, equal to zero. For a long time, this was referred to as the "flatness problem," since no one could think of a good explanation for it. However, while long a difficult thing for theorists to explain, this flatness of space is very fortunate. Had the flatness of space *not* been fantastically small to begin with, the universe would either have collapsed and ended a very short time—a tiny fraction of a second—after it began, or would have undergone such a tremendously rapid expansion that it would have torn matter and even atoms asunder.

So far I have described various quantities, like the strengths of the strong nuclear force and the flatness of space, that had to be "fine–tuned" to very special numerical values to make life as we know it possible. But there are also certain gross qualitative features of the laws of physics that are "anthropically" important. One example is the fact that space is three–dimensional. We take this fact for granted, but we shouldn't. That space has three dimensions is an empirical fact, not a metaphysical necessity. Theoretical physicists study hypothetical universes with other numbers of dimensions all the time. If the world had not had three space dimensions, but four or more of them, the gravitational force between two objects would have depended in a different way upon the distance between them. And that, in turn, would have made it impossible for planets to orbit stably around stars: they would either have plummeted into stars or flown off into space. (Interestingly, the first person to point out this consequence of a different law of gravity was the Anglican clergyman William Paley. Paley was one of the first people to think about anthropic coincidences in the laws of nature.) In the same way, the orbits of electrons in atoms would not have been stable, and life based on chemistry would have been impossible.

On the other hand, had there been *fewer* than three space dimensions, complex organisms would doubtless have been impossible for quite a different reason. Complex neural circuitry, as is needed in a brain, would not be possible in one or two dimensions. If one tries to draw a complicated circuit diagram on a two–dimensional surface, one finds that the wires have to intersect each other many times, leading to short–circuits.

As a final example, the fact that nature obeys the principles of quantum theory is highly important for the possibility of life. It turns out that matter would not be stable in a non–quantum world. People generally suppose that the Heisenberg Uncertainty Principle makes the world, at least at the atomic level, a fuzzier and more indefinite place. However, paradoxical as it may sound, that principle is ultimately responsible for the fact that subatomic particles form stable atoms with well–defined chemical properties. Were it not for the principles of quantum theory, matter would be amorphous and protean to such a degree that it is hard to imagine a living organism being possible.

What do physicists make of such anthropic coincidences? There is a wide spectrum of opinion. Some of the greatest scientists of our time, including Yacov Zel'dovich, Andrei Sakharov, Lev Okun, Martin Rees, and Steven Weinberg, to name but a few, have been interested in them and have devoted study to them. Nevertheless, the subject provokes discomfort and even hostility in much of the physics community, partly due to the specter of teleology. Physicists have a strong instinctive professional aversion to teleological thinking, because, at least in the physical sciences, the scientific revolution was to a large extent made possible by the rejection of teleology in favor of mechanism. I suspect, though, that there is more to this nervousness about anthropic coincidences—namely, the specter of religion.

Yet, scientific skepticism about these ideas is not based entirely on such prejudices. There are several arguments against the idea of anthropic coincidences that must be taken seriously.

First, it is argued that we cannot really know what is necessary for life to arise. Life might take forms that are utterly alien to our experience. While the life that we know about makes use of a certain kind of physics, who knows whether, with different physical laws, completely different possibilities for life might have existed?

This objection has some real force. In some cases, I think, all we can honestly assert is that it appears highly unlikely that life could have arisen had the laws of physics been different in this or that respect—unlikely, but perhaps not utterly impossible. In such questions absolute certainty may not be attainable due to our limited imaginations. However, absolute certainty may be beside the point. We might still be left with strong *indications* that the cosmos was made with us in mind, even if those indications do not add up to a proof. After all, the reasons that scientists like Weinberg, Dawkins, and Gould give for reaching the opposite conclusion are also not subject to proof.

The second objection is that conventional scientific explanations may exist for some if not all of the facts that now appear to be anthropic coincidences. In fact, among the examples I gave of anthropic coincidences I included two where we may already have at least a partial scientific explanation of the facts involved. The fact that the electromagnetic force is much weaker than the strong nuclear force, for instance, is probably partly explained by the idea of "grand unification." There are reasons to believe that the electromagnetic force, the weak interaction, and the strong nuclear force are really all aspects of one underlying "grand unified" force. If that is so, then the strengths of the different forces are not independent of each other, but are tied together in a definite way. In fact, in a typical grand unified model—and many such models have been proposed—the electromagnetic force does indeed come out to be much weaker than the strong nuclear force. Another of the anthropic coincidences concerns the flatness of space. This too is a fact for which we now have a probable explanation: it is thought to be a consequence of an effect called "cosmic inflation."

Thus, it is more than likely that at least some of the facts about the laws of physics that appear favorable to our existence do have conventional scientific explanations. Even if that proved to be true of all of them, however, it would not explain away the coincidental nature of these facts. The critical point was well expressed by the noted astrophysicists Bernard Carr and Martin Rees:

> One day we may have a more physical explanation for some of the relationships . . . that now seem genuine coincidences. For example, [some of them] may eventually be subsumed as a consequence of some presently unformulated unified theory. However, *even if all apparently anthropic coincidences could be explained in this way, it would still be remarkable that the relationships dictated by physical theory happened also to be those propitious for life*. [emphasis added]

In other words, suppose that there are twenty numerical relationships that have to hold in order for life to be possible, and suppose that in some physical theory every one of those twenty relationships happens to hold as a consequence of some underlying physical principle. That would *itself* amount to an astonishing coincidence.

This brings us to the third objection, which is closely related to the second. Einstein famously asked whether God had a choice in how He made the world. Many physicists nowadays suspect not. They suspect that all mathematical relationships in the laws of physics will turn out to be dictated by some deep underlying principles that leave no room for things to have been otherwise. One frequently hears the possibility discussed that the laws of physics are "unique." The idea is that everything about the physical world—the kinds of particles that exist, the kinds of forces and their relative strengths, the number of dimensions of space and its degree of flatness, the energy levels of the carbon–12 nucleus, and so on, down to the smallest detail—may have to be as they are on account of some fundamental physical principles. If so, God could not have the freedom to arrange the laws of nature to be "propitious for life" or otherwise, since His hands were completely tied.

However, this is plainly wrong. Physical principles could not have tied God's hands, for the simple reason that He could have chosen some *other* principles upon which to base the laws of physics. For example, while the relative feebleness of the electromagnetic force, which we saw to be anthropically fortunate, may be a necessary outcome of a "grand unified" framework, it was by no means necessary that the world be built according to such a "grand unified" framework. In fact, we still do not know whether it is. So, in this particular matter God clearly did have a choice—indeed, many choices, as there are many mathematically self–consistent frameworks that involve "grand unification" and many that do not.

As a matter of fact, there are an infinite number of mathematically self–consistent sets of laws of physics that could have been chosen as the basis for the structure of a universe. This is incontestable. When those (good) physicists talk about the laws of physics being possibly "unique," they are speaking very loosely.

What they really have in mind is the idea that a unique set of laws may be necessary if it has to satisfy certain assumed preconditions. For example, many theorists believe that there is only one possible set of laws—"superstring theory"—that can incorporate simultaneously the principles of quantum theory and the principles of Einsteinian gravity. However, there is certainly no reason to suppose a priori that the universe had to incorporate either quantum theory or Einsteinian gravity. In short, the universe could have been made differently, and if it had been life might not have been able to arise. These assertions, it seems to me, can hardly be disputed.

Before one leaps to the conclusion that the anthropic coincidences inevitably point to God, one should be aware of the fact that many of the scientists who have written about anthropic coincidences are atheists. (Steven Weinberg is a notable example.) It is their view that the laws of physics being "propitious" for life, far from pointing to the importance of life or human beings in some cosmic "plan," has a purely naturalistic, scientific explanation. The explanation that they offer is based on an idea that is called the Anthropic Principle. There are various anthropic principles that are discussed, but the only one taken seriously by scientists as being plausible and having any explanatory power is called the Weak Anthropic Principle, or WAP for short. It should be noted that careless writers often talk about "the anthropic principle" when what they really mean is "anthropic coincidences." The two ideas should not be confused: the anthropic coincidences are facts, while the anthropic "principle" is a speculative hypothesis for explaining those facts.

The idea of the Weak Anthropic Principle is easiest to grasp using an analogy. There are many things about conditions on the planet Earth that are propitious for life. If the Earth were much smaller, then it would not be able to retain an atmosphere. If it were much bigger, it would retain a lot of hydrogen in its atmosphere, which might be bad for life. If it were much closer to the sun it would be too hot to have liquid water, if much farther away it would be too cold. Has someone "fine–tuned" conditions here to make life possible? Not necessarily. There are presumably a vast number of planets in the universe. (In the context of present–day theory, it is not unlikely that there are an infinite number.) Some planets are hot, some cold. some big, and some small. They undoubtedly span a vast range of physical and chemical conditions. It seems inevitable that some of them would happen to have the right conditions for life.

To put it another way, if one tried one key in an unknown lock, it would be an astonishing coincidence if it worked. But if one tried a million keys it would not be greatly surprising if one of them did.

The idea of the Weak Anthropic Principle is that the same kind of argument can be used not just about planets, but about universes. Suppose that there are a huge number of universes. Some may have three space dimensions, some two, some four, and so on. In some, the electromagnetic force may be weaker than the strong nuclear force, in others it may be stronger, and in others there may be no such thing as the electromagnetic force at all. That is, all sorts of possible physical laws might be tried out in different universes. If so, it might not be surprising, assuming that a great enough number and variety of universes existed, that some of them would have just the right laws of physics to permit life. And of course, to the inhabitants of such an exceptional universe, it might seem that someone had arranged things in their universe with them in mind. This is an old idea, going back at least to David Hume, who suggested that "many worlds might have been botched and bungled, throughout an eternity, ere this system was struck out."

Before examining this idea critically, one must distinguish two versions of it. In the version that physicists take seriously, the many "universes" are not really distinct and separate universes at all, but domains or regions of one all–encompassing Universe. The domains are far apart in space, or otherwise prevented from communicating with each other. Conditions are assumed to be so different from one domain to another that they appear superficially to have different physical laws. However, at a deeper level all the domains are really controlled by one and the same set of fundamental laws. These laws also control what types of domains the universe has, and how many of each type.

The other version of the idea posits the existence of a large number of universes that really are universes, distinct and unconnected in any way with each other. Each has its own set of physical laws. There is no overarching physical system of which each is a part. One can understand why this version is not discussed among scientists. At least in the many–domains version all the domains are part of the same universe as we, so that, even if we cannot in practice observe them directly, we might hope at least to infer their existence theoretically from a deep understanding of the laws of nature. In the many–universes version, this is not the case.

Let us first consider the many–domains version of the idea. It is not, as many suppose, a foolish or extravagant one. In fact, some of the kinds of theories that fundamental physicists think about nowadays actually imply that the universe must have domains. In such theories the different domains can differ radically from each other, with even different kinds of particles and different forces. Thus it is not unreasonable to suppose that a many–domains version of the Weak Anthropic Principle might turn out to be the explanation for some of the anthropic coincidences. Nevertheless, I do not believe that this would subtract much from the force of the anthropic coincidences as evidence for purpose in the universe. The reason is simple. The whole point of the anthropic coincidences is that the laws of physics have to be very special to allow life to exist. But this requirement is not avoided by the many–domains idea, for the laws of physics also have to be very special to give rise to a universe with domains, especially domains of a sufficiently rich variety to do what the Weak Anthropic Principle demands of them.

One can illustrate the point by means of a rather whimsical analogy. Suppose you were looking for a specific obscure recipe for, say, goulash. If the first book you took at random from the cooking shelf of the library happened to have exactly that recipe, you would regard it as a great coincidence. If you then discovered that the book contained *every* recipe for goulash ever invented, you would cease to regard it as coincidental that it had the one of particular interest to you. But you would be surprised nonetheless, for one does not expect a cookbook to treat that particular category of food so comprehensively. The fact that it happened to be so comprehensive in its selection of goulash, when it was goulash that you needed, would itself count as a remarkable coincidence.

Likewise, it is not something to be taken for granted that the universe would have as many domains as needed for the anthropic coincidences to seem unsurprising. On the contrary, in the kinds of theories physicists have found reason to study, the universe is not nearly so inclusive. True, some of those theories suggest that the universe has domains, but they typically realize only a few possibilities, not the vast smorgasbord of possibilities needed to explain *all* of the many anthropic coincidences that have been identified.

The many–universes version of the anthropic principle is in a way simpler. In the many–domains idea, one has to account for the domains by a physical mechanism. Consequently the laws of physics have to be "engineered," as it were, to produce a universe with a sufficiently rich variety of domains. In the many–universes idea, on the other hand, it is simply posited that many types of universe exist. What types of universe exist and what types do not? That is not a question that the laws of physics can possibly answer, since each universe has *ex hypothesi* its *own* laws of physics. If some kinds of universe exist while others do not, it would seem to suggest that Someone has made choices. Far from destroying the case that a cosmic Designer exists, the many–universes idea only strengthens it.

A last–ditch way out for the opponents of cosmic design would be to say that *all* conceivable universes exist, i.e., any universe that is logically and mathematically self–consistent actually exists. This idea has a breathtaking simplicity. It would explain existence: to exist is to be self–consistent. It would remove the need for a Designer or a Creator. Whereas the "unique laws of physics" idea got rid of a Designer by saying that there are no choices for a Designer to make as there is only one real possibility, here the Designer is eliminated by saying that there are infinitely many possibilities, but that no one has selected among them.

There is, however, a fatal problem with this way of getting rid of the cosmic Designer. It cannot explain why we live in a universe that is so astonishingly lawful. Among all the logically possible universes, ones that have the perfection of order and lawfulness that ours displays are highly exceptional, just as among all possible rocks, a perfect gem that has absolutely no flaws in it is almost infinitely unlikely. Why doesn't our universe exhibit occasional departures from its regularities—the regularities we call the laws of physics—just as gemstones have occasional departures from their regularities? No answer to this is possible. If all possible universes exist, it becomes a tremendous miracle that we live in a universe of perfect, or nearly perfect, lawfulness. It is a miracle, in other words, that miracles do not occur around us all the time.

The Weak Anthropic Principle, whether in its many–universes or many–domains versions, cannot succeed in explaining the anthropic coincidences away or making them any less coincidental. In the final analysis one cannot escape from two very basic facts: the laws of nature did not have to be as they are; and the laws of nature had to be very special in form if life were to be possible. In my view these facts lend themselves most naturally to a religious interpretation. Certainly, they tend to undercut the claim so often confidently made by materialists that the discoveries of science point to a universe without meaning or purpose, in which man is an accidental by–product.

Having said all this, we remain with a question very troubling to many: Why is the universe so big? How can we claim to be important in a universe that dwarfs us in its scales of space and time? There is at least a paradox here. It is a paradox that was not lost upon the Psalmist, who exclaimed, “When I consider the heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; What is man, that thou art mindful of him, and the son of man, that thou visit est him?”

One answer, of course, is the traditional one. The universe was not made only for our benefit. As the Psalmist also said, “the heavens proclaim the glory of God.” If it is the glory of God that they proclaim, then there is no particular reason why they should have to be made to human scale. In fact, in the fifteenth century Nicolas of Cusa argued that only a universe of infinite extent would be worthy of the Creator and able to manifest His glory.

The traditional answer is a good one, but there may be another. It turns out that the very age and vastness of the universe may have an “anthropic” significance. Life emerged in our universe in a way that required great stretches of time. As we have seen, most of the elements needed for life were made deep in stars. Those stars had to explode to disperse those elements and make them available before life could even begin to evolve. That whole process alone required billions of years. The evolution of human life from those elements required billions of years more. Thus, the briefness of human life spans and even of human history compared with the age of the universe may simply be a matter of physical necessity, given the developmental way that God seems to prefer to work. It takes longer for a tree to grow to maturity than the fruit of the tree lasts. It took much longer for the universe to grow to maturity than we last.

Physics can also suggest why the universe has to be so large. The laws of gravity discovered by Einstein relate the size of the universe directly to its age. The fact that the universe is many billions of light–years across is related to the fact that it has lasted several billions of years. Perhaps we would be less daunted by a cozy little universe the size, say, of a continent. But such a universe would have lasted only a few milliseconds. Even a universe the size of the solar system would have lasted only a few hours. A universe constructed in such a way as to evolve life may well have had to extend widely in space as well as in time. It may well be that the frightening expanses that are so often said to be a sign of human insignificance may actually, like so many other features of our strange universe, point to man, as they also proclaim the glory of God.

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