

A Designer Universe?

by Steven Weinberg

Professor of Physics, University of Texas at Austin

Winner of the 1979 Nobel Prize in Physics.

I have been asked to comment on whether the universe shows signs of having been designed.¹ I don't see how it's possible to talk about this without having at least some vague idea of what a designer would be like. Any possible universe could be explained as the work of some sort of designer. Even a universe that is completely chaotic, without any laws or regularities at all, could be supposed to have been designed by an idiot.

The question that seems to me to be worth answering, and perhaps not impossible to answer, is whether the universe shows signs of having been designed by a deity more or less like those of traditional monotheistic religions—not necessarily a figure from the ceiling of the Sistine Chapel, but at least some sort of personality, some intelligence, who created the universe and has some special concern with life, in particular with human life. I expect that this is not the idea of a designer held by many here. You may tell me that you are thinking of something much more abstract, some cosmic spirit of order and harmony, as Einstein did. You are certainly free to think that way, but then I don't know why you use words like 'designer' or 'God,' except perhaps as a form of protective coloration.

It used to be obvious that the world was designed by some sort of intelligence. What else could account for fire and rain and lightning and earthquakes? Above all, the wonderful abilities of living things seemed to point to a creator who had a special interest in life. Today we understand most of these things in terms of physical forces acting under impersonal laws. We don't yet know the most fundamental laws, and we can't work out all the consequences of the laws we do

know. The human mind remains extraordinarily difficult to understand, but so is the weather. We can't predict whether it will rain one month from today, but we do know the rules that govern the rain, even though we can't always calculate their consequences. I see nothing about the human mind any more than about the weather that stands out as beyond the hope of understanding as a consequence of impersonal laws acting over billions of years.

There do not seem to be any exceptions to this natural order, any miracles. I have the impression that these days most theologians are embarrassed by talk of miracles, but the great monotheistic faiths are founded on miracle stories—the burning bush, the empty tomb, an angel dictating the Koran to Mohammed—and some of these faiths teach that miracles continue at the present day. The evidence for all these miracles seems to me to be considerably weaker than the evidence for cold fusion, and I don't believe in cold fusion. Above all, today we understand that even human beings are the result of natural selection acting over millions of years of breeding and eating.

I'd guess that if we were to see the hand of the designer anywhere, it would be in the fundamental principles, the final laws of nature, the book of rules that govern all natural phenomena. We don't know the final laws yet, but as far as we have been able to see, they are utterly impersonal and quite without any special role for life. There is no life force. As Richard Feynman has said, when you look at the universe and understand its laws, 'the theory that it is all arranged as a stage for God to watch man's struggle for good and evil seems inadequate.'

True, when quantum mechanics was new, some physicists thought that it put humans back into the picture, because the principles of quantum mechanics tell us how to calculate the probabilities of various results that might be found by a human observer. But, starting with the work of Hugh Everett forty years ago, the tendency of physicists who think deeply about these things has been to reformulate quantum mechanics in an entirely objective way, with observers treated just like everything else. I don't know if this program has been completely successful yet, but I think it will be.

I have to admit that, even when physicists will have gone as far as they can go, when we have a final theory, we will not have a completely satisfying picture of the world, because we will still be left with the question 'why?' Why this theory, rather than some other theory? For example, why is the world described by quantum mechanics? Quantum mechanics is the one part of our present physics that is likely to survive intact in any future theory, but there is nothing logically inevitable about quantum mechanics; I can imagine a universe governed by Newtonian mechanics instead. So there seems to be an irreducible mystery that science will not eliminate.

But religious theories of design have the same problem. Either you mean something definite by a God, a designer, or you don't. If you don't, then what are we talking about? If you do mean something definite by 'God' or 'design,' if for instance you believe in a God who is jealous, or loving, or intelligent, or whimsical, then you still must confront the question 'why?' A religion may assert that the universe is governed by that sort of God, rather than some other sort of God, and it may offer evidence for this belief, but it cannot explain why this should be so.

In this respect, it seems to me that physics is in a better position to give us a partly satisfying explanation of the world than religion can ever be, because although physicists won't be able to explain why the laws of nature are what they are and not something completely different, at least we may be able to explain why they are not slightly different. For instance, no one has been able to think of a logically consistent alternative to quantum mechanics that is only slightly different. Once you start trying to make small changes in quantum mechanics, you get into theories with negative probabilities or other logical absurdities. When you combine quantum mechanics with relativity you increase its logical fragility. You find that unless you arrange the theory in just the right way you get nonsense, like effects preceding causes, or infinite probabilities. Religious theories, on the other hand, seem to be infinitely flexible, with nothing to prevent the invention of deities of any conceivable sort.

Now, it doesn't settle the matter for me to say that we cannot see the hand of a designer in what we know about the fundamental principles of science. It might be that, although these principles do not refer explicitly to life, much less human life, they are nevertheless craftily designed to bring it about.

Some physicists have argued that certain constants of nature have values that seem to have been mysteriously fine-tuned to just the values that allow for the possibility of life, in a way that could only be explained by the intervention of a designer with some special concern for life. I am not impressed with these supposed instances of fine-tuning. For instance, one of the most frequently quoted examples of fine-tuning has to do with a property of the nucleus of the carbon atom. The matter left over from the first few minutes of the universe was almost entirely hydrogen and helium, with virtually none of the heavier elements like carbon, nitrogen, and oxygen that seem to be necessary for life. The heavy elements that we find on earth were built up hundreds of millions of years later in a first generation of stars, and then spewed out into the interstellar gas out of which our solar system eventually formed.

The first step in the sequence of nuclear reactions that created the heavy elements in early stars is usually the formation of a carbon nucleus out of three helium nuclei. There is a negligible chance of producing a carbon nucleus in its normal state (the state of lowest energy) in collisions of three helium nuclei, but it would be possible to produce appreciable amounts of carbon in stars if the carbon nucleus could exist in a radioactive state with an energy roughly 7 million electron volts (MeV) above the energy of the normal state, matching the energy of three helium nuclei, but (for reasons I'll come to presently) not more than 7.7 MeV above the normal state.

This radioactive state of a carbon nucleus could be easily formed in stars from three helium nuclei. After that, there would be no problem in producing ordinary carbon; the carbon nucleus in its radioactive state would spontaneously emit light and turn into carbon in its normal nonradioactive state, the state found on earth. The critical point in producing carbon is the existence of a radioactive state that

can be produced in collisions of three helium nuclei.

In fact, the carbon nucleus is known experimentally to have just such a radioactive state, with an energy 7.65 MeV above the normal state. At first sight this may seem like a pretty close call; the energy of this radioactive state of carbon misses being too high to allow the formation of carbon (and hence of us) by only 0.05 MeV, which is less than one percent of 7.65 MeV. It may appear that the constants of nature on which the properties of all nuclei depend have been carefully fine-tuned to make life possible.

Looked at more closely, the fine-tuning of the constants of nature here does not seem so fine. We have to consider the reason why the formation of carbon in stars requires the existence of a radioactive state of carbon with an energy not more than 7.7 MeV above the energy of the normal state. The reason is that the carbon nuclei in this state are actually formed in a two-step process: first, two helium nuclei combine to form the unstable nucleus of a beryllium isotope, beryllium 8, which occasionally, before it falls apart, captures another helium nucleus, forming a carbon nucleus in its radioactive state, which then decays into normal carbon. The total energy of the beryllium 8 nucleus and a helium nucleus at rest is 7.4 MeV above the energy of the normal state of the carbon nucleus; so if the energy of the radioactive state of carbon were more than 7.7 MeV it could only be formed in a collision of a helium nucleus and a beryllium 8 nucleus if the energy of motion of these two nuclei were at least 0.3 MeV—an energy which is extremely unlikely at the temperatures found in stars.

Thus the crucial thing that affects the production of carbon in stars is not the 7.65 MeV energy of the radioactive state of carbon above its normal state, but the 0.25 MeV energy of the radioactive state, an unstable composite of a beryllium 8 nucleus and a helium nucleus, above the energy of those nuclei at rest.² This energy misses being too high for the production of carbon by a fractional amount of 0.05 MeV/0.25 MeV, or 20 percent, which is not such a close call after all.

This conclusion about the lessons to be learned from carbon synthesis is

somewhat controversial. In any case, there is one constant whose value does seem remarkably well adjusted in our favor. It is the energy density of empty space, also known as the cosmological constant. It could have any value, but from first principles one would guess that this constant should be very large, and could be positive or negative. If large and positive, the cosmological constant would act as a repulsive force that increases with distance, a force that would prevent matter from clumping together in the early universe, the process that was the first step in forming galaxies and stars and planets and people. If large and negative the cosmological constant would act as an attractive force increasing with distance, a force that would almost immediately reverse the expansion of the universe and cause it to recollapse, leaving no time for the evolution of life. In fact, astronomical observations show that the cosmological constant is quite small, very much smaller than would have been guessed from first principles.

It is still too early to tell whether there is some fundamental principle that can explain why the cosmological constant must be this small. But even if there is no such principle, recent developments in cosmology offer the possibility of an explanation of why the measured values of the cosmological constant and other physical constants are favorable for the appearance of intelligent life. According to the 'chaotic inflation' theories of André Linde and others, the expanding cloud of billions of galaxies that we call the big bang may be just one fragment of a much larger universe in which big bangs go off all the time, each one with different values for the fundamental constants.

In any such picture, in which the universe contains many parts with different values for what we call the constants of nature, there would be no difficulty in understanding why these constants take values favorable to intelligent life. There would be a vast number of big bangs in which the constants of nature take values unfavorable for life, and many fewer where life is possible. You don't have to invoke a benevolent designer to explain why we are in one of the parts of the universe where life is possible: in all the other parts of the universe there is no one to raise the question.³ If any theory of this general type turns out to be correct, then to conclude that the constants of nature have been fine-tuned by a

benevolent designer would be like saying, 'Isn't it wonderful that God put us here on earth, where there's water and air and the surface gravity and temperature are so comfortable, rather than some horrid place, like Mercury or Pluto?' Where else in the solar system other than on earth could we have evolved?

Reasoning like this is called 'anthropic.' Sometimes it just amounts to an assertion that the laws of nature are what they are so that we can exist, without further explanation. This seems to me to be little more than mystical mumbo jumbo. On the other hand, if there really is a large number of worlds in which some constants take different values, then the anthropic explanation of why in our world they take values favorable for life is just common sense, like explaining why we live on the earth rather than Mercury or Pluto. The actual value of the cosmological constant, recently measured by observations of the motion of distant supernovas, is about what you would expect from this sort of argument: it is just about small enough so that it does not interfere much with the formation of galaxies. But we don't yet know enough about physics to tell whether there are different parts of the universe in which what are usually called the constants of physics really do take different values. This is not a hopeless question; we will be able to answer it when we know more about the quantum theory of gravitation than we do now.

It would be evidence for a benevolent designer if life were better than could be expected on other grounds. To judge this, we should keep in mind that a certain capacity for pleasure would readily have evolved through natural selection, as an incentive to animals who need to eat and breed in order to pass on their genes. It may not be likely that natural selection on any one planet would produce animals who are fortunate enough to have the leisure and the ability to do science and think abstractly, but our sample of what is produced by evolution is very biased, by the fact that it is only in these fortunate cases that there is anyone thinking about cosmic design. Astronomers call this a selection effect.

The universe is very large, and perhaps infinite, so it should be no surprise that, among the enormous number of planets that may support only unintelligent life

and the still vaster number that cannot support life at all, there is some tiny fraction on which there are living beings who are capable of thinking about the universe, as we are doing here. A journalist who has been assigned to interview lottery winners may come to feel that some special providence has been at work on their behalf, but he should keep in mind the much larger number of lottery players whom he is not interviewing because they haven't won anything. Thus, to judge whether our lives show evidence for a benevolent designer, we have not only to ask whether life is better than would be expected in any case from what we know about natural selection, but we need also to take into account the bias introduced by the fact that it is we who are thinking about the problem.

This is a question that you all will have to answer for yourselves. Being a physicist is no help with questions like this, so I have to speak from my own experience. My life has been remarkably happy, perhaps in the upper 99.99 percentile of human happiness, but even so, I have seen a mother die painfully of cancer, a father's personality destroyed by Alzheimer's disease, and scores of second and third cousins murdered in the Holocaust. Signs of a benevolent designer are pretty well hidden.

The prevalence of evil and misery has always bothered those who believe in a benevolent and omnipotent God. Sometimes God is excused by pointing to the need for free will. Milton gives God this argument in *Paradise Lost*:

*I formed them free, and free they must remain
Till they enthrall themselves: I else must change
Their nature, and revoke the high decree
Unchangeable, eternal, which ordained
Their freedom; they themselves ordained their fall.*

It seems a bit unfair to my relatives to be murdered in order to provide an opportunity for free will for Germans, but even putting that aside, how does free will account for cancer? Is it an opportunity of free will for tumors?

I don't need to argue here that the evil in the world proves that the universe is not designed, but only that there are no signs of benevolence that might have shown the hand of a designer. But in fact the perception that God cannot be benevolent is very old. Plays by Aeschylus and Euripides make a quite explicit statement that the gods are selfish and cruel, though they expect better behavior from humans. God in the Old Testament tells us to bash the heads of infidels and demands of us that we be willing to sacrifice our children's lives at His orders, and the God of traditional Christianity and Islam damns us for eternity if we do not worship him in the right manner. Is this a nice way to behave? I know, I know, we are not supposed to judge God according to human standards, but you see the problem here: If we are not yet convinced of His existence, and are looking for signs of His benevolence, then what other standards can we use?

The issues that I have been asked to address here will seem to many to be terribly old-fashioned. The 'argument from design' made by the English theologian William Paley is not on most peoples' minds these days. The prestige of religion seems today to derive from what people take to be its moral influence, rather than from what they may think has been its success in accounting for what we see in nature. Conversely, I have to admit that, although I really don't believe in a cosmic designer, the reason that I am taking the trouble to argue about it is that I think that on balance the moral influence of religion has been awful.

This is much too big a question to be settled here. On one side, I could point out endless examples of the harm done by religious enthusiasm, through a long history of pogroms, crusades, and jihads. In our own century it was a Muslim zealot who killed Sadat, a Jewish zealot who killed Rabin, and a Hindu zealot who killed Gandhi. No one would say that Hitler was a Christian zealot, but it is hard to imagine Nazism taking the form it did without the foundation provided by centuries of Christian anti-Semitism. On the other side, many admirers of religion would set countless examples of the good done by religion. For instance, in his recent book *Imagined Worlds*, the distinguished physicist Freeman Dyson has emphasized the role of religious belief in the suppression of slavery. I'd like to comment briefly on this point, not to try to prove anything with one example but

just to illustrate what I think about the moral influence of religion.

It is certainly true that the campaign against slavery and the slave trade was greatly strengthened by devout Christians, including the Evangelical layman William Wilberforce in England and the Unitarian minister William Ellery Channing in America. But Christianity, like other great world religions, lived comfortably with slavery for many centuries, and slavery was endorsed in the New Testament. So what was different for anti-slavery Christians like Wilberforce and Channing? There had been no discovery of new sacred scriptures, and neither Wilberforce nor Channing claimed to have received any supernatural revelations. Rather, the eighteenth century had seen a widespread increase in rationality and humanitarianism that led others—for instance, Adam Smith, Jeremy Bentham, and Richard Brinsley Sheridan—also to oppose slavery, on grounds having nothing to do with religion. Lord Mansfield, the author of the decision in *Somerset's Case*, which ended slavery in England (though not its colonies), was no more than conventionally religious, and his decision did not mention religious arguments. Although Wilberforce was the instigator of the campaign against the slave trade in the 1790s, this movement had essential support from many in Parliament like Fox and Pitt, who were not known for their piety. As far as I can tell, the moral tone of religion benefited more from the spirit of the times than the spirit of the times benefited from religion.

Where religion did make a difference, it was more in support of slavery than in opposition to it. Arguments from scripture were used in Parliament to defend the slave trade. Frederick Douglass told in his *Narrative* how his condition as a slave became worse when his master underwent a religious conversion that allowed him to justify slavery as the punishment of the children of Ham. Mark Twain described his mother as a genuinely good person, whose soft heart pitied even Satan, but who had no doubt about the legitimacy of slavery, because in years of living in antebellum Missouri she had never heard any sermon opposing slavery, but only countless sermons preaching that slavery was God's will. With or without religion, good people can behave well and bad people can do evil; but for good people to do evil—that takes religion.

In an e-mail message from the American Association for the Advancement of Science I learned that the aim of this conference is to have a constructive dialogue between science and religion. I am all in favor of a dialogue between science and religion, but not a constructive dialogue. One of the great achievements of science has been, if not to make it impossible for intelligent people to be religious, then at least to make it possible for them not to be religious. We should not retreat from this accomplishment.

1 This article is based on a talk given in April 1999 at the Conference on Cosmic Design of the American Association for the Advancement of Science in Washington, D.C. [back](#)

2 This was pointed out in a 1989 paper by M. Livio, D. Hollowell, A. Weiss, and J.W. Truran ('The anthropic significance of the existence of an excited state of ^{12}C ,' Nature, Vol. 340, No. 6231, July 27, 1989). They did the calculation quoted here of the 7.7 MeV maximum energy of the radioactive state of carbon, above which little carbon is formed in stars. [back](#)

3 The same conclusion may be reached in a more subtle way when quantum mechanics is applied to the whole universe. Through a reinterpretation of earlier work by Stephen Hawking, Sidney Coleman has shown how quantum mechanical effects can lead to a split of the history of the universe (more precisely, in what is called the wave function of the universe) into a huge number of separate possibilities, each one corresponding to a different set of fundamental constants. See Sidney Coleman, 'Black Holes as Red Herrings: Topological fluctuations and the loss of quantum coherence,' Nuclear Physics, Vol. B307 (1988), p. 867. [back](#)

Biography



Steven Weinberg was educated at Cornell, Copenhagen, and Princeton, and taught at Columbia, Berkeley, M.I.T., and Harvard, where from 1973 to 1982 he was Higgins Professor of Physics. In 1982 he moved to The University of Texas at Austin and founded its Theory Group. At Texas he holds the Josey Regental Chair of Science and is a member of the Physics and Astronomy Departments. His research has spanned a broad range of topics in quantum field theory, elementary particle physics, and cosmology, and has been honored with numerous awards, including the Nobel Prize in Physics, the National Medal of Science, the Heinemann Prize in Mathematical Physics, the Cresson Medal of the Franklin Institute, the Madison Medal of Princeton University, and the Oppenheimer Prize. He also holds honorary doctoral degrees from a dozen universities. He is a member of the National Academy of Science, the Royal Society of London, the American Academy of Arts and Sciences, the International Astronomical Union, and the American Philosophical Society. In addition to the well-known treatise, *Gravitation and Cosmology*, he has written several books for general readers, including the prize-winning *The First Three Minutes* (now translated into 22 foreign languages), *The Discovery of Subatomic Particles*, and most recently *Dreams of a Final Theory*. He has written a textbook *The Quantum Theory of Fields*, Vol. I. and Vol. II.

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