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What is the “fine-tuning” of the universe, and how does it serve as a “pointer to God”?

> "The more I examine the universe, and the details of its architecture, the more evidence I find that the Universe in some sense must have known we were coming." — *Freeman Dyson*[1]

> "A bottom-up approach to cosmology either requires one to postulate an initial state of the Universe that is carefully fine-tuned — as if prescribed by an outside agency — or it requires one to invoke the notion of eternal inflation, a mighty speculative notion to the generation of many different Universes, which prevents one from predicting what a typical observer would see." — *Stephen Hawking*[2]

Fine-Tuning and Pointers to God

Fine-tuning refers to the surprising precision of nature’s physical constants and the beginning state of the universe. Both of these features converge as potential pointers to a Creator. To explain the present state of the universe, scientific theories require that the physical constants of nature — like the strength of gravity — and the beginning state of the Universe — like its density — have

extremely precise values. The slightest variation from their actual values results in an early universe that never becomes capable of hosting life. For this reason, the universe seems finely-tuned for life. This observation is referred to as the anthropic principle, a term whose definition has taken many variations over the years.[3]

Constants of Nature

The fine-tuning of the universe is seen most clearly in the values of the constants of nature. There are many such constants, the best known of which specify the strength of the four forces of nature: the strong nuclear force, the weak nuclear force, the electromagnetic force, and gravity. If these forces took on even slightly different strengths, the consequences for life would be devastating.[4] Two of these in particular, the strong and electromagnetic forces, are responsible for the unusually efficient production of carbon, the element upon which all known life is based. The forces cooperate in such a way as to create a coincidental match up of energy levels, which enables the production of carbon from the fusing of three helium atoms. For three helium atoms to collide and create carbon is very unlikely, however, because under normal circumstances, the energies would not match up perfectly, and the three helium atoms would come apart before they had time to fuse into carbon. It takes a little extra time to deal with the energy mismatch. But, if there is a statistically unusual match of the energies, then the process is much faster. The slightest change to either the strong or electromagnetic forces would alter the energy levels, resulting in greatly reduced production of carbon and an ultimately uninhabitable universe. In the 1950s, Cambridge University astronomer Fred Hoyle recognized the precision of the energy match up, called carbon resonance, and made the following observation:

> "A commonsense interpretation of the facts suggests that a super-intellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature. The numbers one calculates from the facts seem to me so overwhelming as to put this conclusion almost beyond question." [5]

Hoyle did not mean to argue in favor of divine intervention as an answer. The scientific explanation of carbon's development was readily accessible, although this explanation offers no insight into why the fundamental forces cooperated to produce the unusual energy match up. Hoyle's remark should be understood as an acknowledgement of how startling it is that the universe has the exact properties that enable the existence of life.

Consider also the strength of gravity. When the Big Bang occurred billions of years ago, the matter in the universe was randomly distributed. There were no stars, planets or galaxies—just atoms floating about in the dark void of space. As the universe expanded outwards from the Big Bang,

gravity pulled ever so gently on the atoms, gathering them into clumps that eventually became stars and galaxies. But gravity had to have just the right force—if it was a bit stronger, it would have pulled all the atoms together into one big ball. The Big Bang—and our prospects—would have ended quickly in a Big Crunch. And if gravity was a bit weaker, the expanding universe would have distributed the atoms so widely that they would never have been gathered into stars and galaxies. The strength of gravity has to be exactly for stars to form. But what do we mean by “exactly”? Well, it turns out that if we change gravity by even a tiny fraction of a percent—enough so that you would be, say, one billionth of a gram heavier or lighter—the universe becomes so different that there are no stars, galaxies, or planets. And without planets, there would be no life. The other constants of nature possess this same feature. Change any of them, and the universe, like Robert Frost’s traveler, moves along a very different path. And remarkably, every one of these different paths leads to a universe without life in it. Our universe is friendly to life, but only because the past fifteen billion years have unfolded in a particular way that led to a habitable planet with liquid water and rich chemistry.

There are many other finely-tuned constants of nature besides the strengths of these forces. Consider the ratio of masses for protons and electrons, as a final example. The mass of a proton is roughly 1836.1526 times the mass of the electron.[6] Were this ratio changed by any significant degree, the stability of many common chemicals would be compromised. In the end, this would prevent the formation of such molecules as DNA, the building blocks of life.[7] But with regard to the development of life on Earth, it is sometimes claimed that natural selection would find a way for life to develop no matter what the circumstances. In this way, nature is sometimes said to tune itself. However, the fine-tuning of carbon is even responsible for nature’s ability to tune itself to any degree. As professor Alister McGrath has pointed out:

> "[The entire biological] evolutionary process depends upon the unusual chemistry of carbon, which allows it to bond to itself, as well as other elements, creating highly complex molecules that are stable over prevailing terrestrial temperatures, and are capable of conveying genetic information (especially DNA). […] Whereas it might be argued that nature creates its own fine-tuning, this can only be done if the primordial constituents of the universe are such that an evolutionary process can be initiated. The unique chemistry of carbon is the ultimate foundation of the capacity of nature to tune itself." [8]

Initial Conditions

Fine-tuning is also evident in the "initial conditions" or the beginning state of the universe. The

initial conditions of the universe include such information as the expansion energy of the Big Bang, the overall amount of matter that was present, the ratio of matter to antimatter, the initial rate of the universe's expansion and even the degree of its entropy.

Consider the expansion rate of the Big Bang. If it was greater, so the early universe expanded faster, the matter in the universe would have become so diffuse that gravity could never have gathered it into stars and galaxies. If it was less, so the early universe expanded more slowly, gravity could have overwhelmed the expansion and pulled all the matter back into a black hole. The expansion rate was just right, so that the universe could have stars in it.

Another interesting example of a finely-tuned initial condition is the critical density of the universe. In order to evolve in a life-sustaining manner, the universe must have maintained an extremely precise overall density. The precision of density must have been so great that a change of one part in 10^{15} (i.e. 0.0000000000001%) would have resulted in a collapse, or big crunch, occurring far too early for life to have developed, or there would have been an expansion so rapid that no stars, galaxies or life could have formed.[9] This degree of precision would be like a blindfolded man choosing a single lucky penny in a pile large enough to pay off the United States' national debt.

Responses to Fine-Tuning

Needless to say, the preceding examples carry significant implications for understanding the universe. With some thought, it seems that out of an unfathomable number of possibilities, our universe is one of very few which is capable of hosting life. Consequently, many of these observations have been used as pointers to God.

Fine-Tuning vs. Irreducible Complexity

Before continuing the discussion, it is important to distinguish these pointers to God from the biological arguments of irreducible complexity, which have a similar form. Fine-tuning provides examples of how nature is able to produce the current complexity of life, and when one reflects upon the unlikelihood of these examples, it may have the potential to point to a creator. In the case of irreducible complexity, however, the argument is advanced to suggest that nature cannot account for our present state of existence without relying upon direct, miraculous, divine intervention somewhere in the process.[10] While an argument of irreducible complexity would be shattered by a scientific explanation, these pointers to God are much less vulnerable to dismissal on the basis of future scientific explanations. However, pointers to God also draw attention to the splendid precision of nature's laws towards the evolution of

life.

A Lucky Accident

Not surprisingly, fine-tuning arguments unsettle those who embrace the philosophy of naturalism, since a straightforward interpretation of the evidence points in favor of an intelligent creator. Some of the naturalist responses are common and are worth mentioning here. The first amounts to a nonchalant shrugging of the shoulders. Many adherents to philosophical naturalism give a response along the following lines: Because humans exist, the laws of nature clearly must be the ones compatible with life. Otherwise, we simply wouldn't be here to notice the fact. To argue against this line of reasoning, John Leslie makes the analogy of surviving an execution at a firing squad completely unharmed.[11] Here, Leslie argues that the naturalist's argument above is analogous to saying, "Of course all of the shots missed, otherwise I wouldn't be here to notice that I'm still alive!" A much more logical approach would be to seek out an explanation for why such an unlikely event occurred. A good scientific explanation satisfies curiosity, whereas this kind of explanation does nothing to offer any resolution.

An Inevitability

From a more scientific standpoint, it is often claimed that the theory of inflation gives an adequate explanation for such precision and balance. The theory of inflation states that in the early stages of cosmological evolution, the universe underwent a period of exponential expansion. By proposing the right kinds of inflationary models, it is possible to show that some of the examples above — most importantly the critical density of the universe — would naturally take on the appropriate values. In this way, some of the universe's fine-tuning seems to be explained away. Whether inflation occurs is a subject of debate. However, most theoretical physicists agree that some form of inflation took place, and more importantly this phenomenon could indeed explain many examples of fine-tuning. But what is not always included in the description of these inflation theories, is the extra fine-tuning the theories themselves require. In order to produce such an enormous inflationary rate of expansion — and to result in the necessary values for our universe's critical density — inflation theories rely upon two or more parameters to take on particularly precise values. So precise are these values that the problem of fine-tuning remains and is only pushed one step back. A second naturalist response is to suppose that the finely-tuned features of our world will someday show themselves to have been inevitable. That is, with an increase in our understanding of physics, it is possible that one day we will discover a Theory of Everything through which all

other facts of physics could be explained. Such a theory might even explain why the universal constants and physical laws have to have such specific values. However, each of the finely-tuned features of our world put certain restrictions on the possibilities for the possible Theory of Everything. In the end, only a few specific theories would suffice, and this essentially results in a fine-tuning problem even for Theories of Everything.[12]

The Multiverse

There is a final response, known as the multiverse hypothesis. The multiverse hypothesis claims that there are many other universes in addition to our own. Each of these has different properties, and different values of the basic constants of physics. If the number of these universes is extremely large, it would be less surprising that one of them would happen to provide the specific conditions for life. At first glance, the proposition of many other universes sounds impressively scientific. However, one must keep in mind that the likelihood of ever being able to observe evidence of another universe is extremely remote, since it is unlikely that information could ever pass from one universe to another. Furthermore, there is no guarantee that the process which produces all of these universes would randomly set all the physical parameters in such a way that every possibility is realized. It could be that there are constraints on the characteristics of these many universes and that the production process itself would have to be fine-tuned in some way to guarantee that we get enough variety of universes to account for our remarkable cosmic home. Additional problems arise with the details of proposing a multiverse, which are enumerated in the suggested readings below.

Consulted Experts:
The BioLogos Foundation is grateful for the assistance of Owen Gingerich in drafting this response.

Notes

- Image from NASA: http://hubblesite.org/gallery/album/nebula/pr2009005a/large_web/npp/all/. Copyright information can be found here: http://hubblesite.org/about_us/copyright.php.

1. Freeman Dyson, *Disturbing the Universe*. New York: Harper and Row, 1979.
2. S.W. Hawking and Thomas Hertog, *Populating the Landscape: A Top Down Approach* (10 Feb 2006) (accessed February 5, 2009). As also in Appendix A in John Polkinghorne and Nicholas Beale, *Questions of Truth* (Louisville, KY[0]: Westminster John Knox Press, 2009).

3. One major contribution to the subject was: John D. Barrow, *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986). For more about the different uses of the term anthropic principle, see John Polkinghorne, *The Anthropic Principle and the Science and Religion Debate*, Faraday Papers, no. 4 (2007).
4. Rodney D. Holder, "Is the Universe Designed?" Faraday Papers, no. 10 (2007). See also John Polkinghorne, "The Science and Religion Debate : An Introduction," Faraday Papers, no. 1 (2007), and Collins, The Language of God: A Scientist Presents Evidence for Belief.
5. Fred Hoyle, "The Universe: Some Past and Present Reflections," Engineering and Science (1981): 12. Quoted in: Holder, "Is the Universe Designed?"
6. The National Institute of Standards and Technology, "Reference on Constants, Units, and Uncertainty: Proton-Electron Mass Ratio," NIST Physics Laboratory, http://physics.nist.gov/cgi-bin/cuu/Value?mpsme (accessed February 5, 2009).
7. Holder, "Is the Universe Designed?"
8. Alister McGrath, A Finely-Tuned Universe: The Quest for God in Science and Theology (Louisville, KY: Westminster John Knox Press, 2009), 176. For further reading about the biological fine tuning of the environment, see specifically chapters 10 and 11.
9. Francis S. Collins, *The Language of God: A Scientist Presents Evidence for Belief* (New York: Free Press, 2006), 72-73. Specific numbers were taken from Appendix A in John Polkinghorne and Nicholas Beale, *Questions of Truth* (Louisville, KY[0]: Westminster John Knox Press, 2009). See also Rodney D. Holder, "Is the Universe Designed?" Faraday Papers, no. 10 (2007).
10. For Dr. Collins' response to Irreducible Complexity, see Collins, The Language of God: A Scientist Presents Evidence for Belief. See also Question 26, on Evolution and the Complexity of Life.
11. John Leslie, Universes (London and New York: Routledge, 1989), 13-14. Quoted in: Polkinghorne, "The Science and Religion Debate:An Introduction."
12. Holder, "Is the Universe Designed?" and Polkinghorne, "The Science and Religion Debate: An Introduction."

Further Reading

Articles

- Holder, Rodney D. "Is the Universe Designed? (PDF)" *Faraday Papers*, no. 10 (2007).
- Hoyle, Fred. "The Universe: Some Past and Present Reflections." *Engineering and Science* (1981): 12.
- Polkinghorne, John. "The Anthropic Principle and the Science and Religion Debate

(PDF).” *Faraday Papers*, no. 4 (2007).
- Polkinghorne, John. "The Science and Religion Debate : An Introduction (PDF)." *Faraday Papers*, no. 1 (2007).
- Poole, Mike. “Am I Significant in the Universe, or just an Accident? (PDF)” *Christians in Science*.

Lectures

- The Faraday Institute for Science and Religion. “Physics and Cosmology.”

Books

- Barrow, John, Wheeler, John, and Frank Tipler. *The Anthropic Cosmological Principle.* Oxford: Oxford University Press, 1986.
- Davies, Paul. *Cosmic Jackpot: Why Our Universe Is Just Right for Life*. Great Britain: The Penguin Press, 2006.
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- McGrath, Alister E. *A Fine-Tuned Universe: The Quest for God in Science and Theology*. Louisville, KY: Westminster John Knox Press, 2009.
- Polkinghorne, John, and Nicholas Beale. “Question 20.” In *Questions of Truth*. Louisville, KY: Westminster John Knox Press, 2009.
- Polkinghorne, John, and Nicholas Beale. “Question 21.” In *Questions of Truth*. Louisville, KY: Westminster John Knox Press, 2009.
