LIST OF FINE-TUNING PARAMETERS

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Jay W. Richards, "List of Fine-Tuning Parameters"

"Fine-tuning" refers to various features of the universe that are necessary conditions for the existence of complex life. Such features include the **initial conditions and "brute facts"** of the universe as a whole, the **laws of nature or the numerical constants present in those laws** (such as the gravitational force constant), and **local features** of habitable planets (such as a planet's distance from its host star).

The basic idea is that these features must fall within a very narrow range of possible values for chemical-based life to be possible.

Some popular examples are subject to dispute. And there are some complicated philosophical debates about how to calculate probabilities. Nevertheless, there are many well-established examples of fine-tuning, which are widely accepted even by scientists who are generally hostile to theism and design. For instance, Stephen Hawking has admitted: "The remarkable fact is that the values of these numbers [the constants of physics] seem to have been very finely adjusted to make possible the development of life." (*A Brief History of Time*, p. 125) Here are the most celebrated and widely accepted examples of fine-tuning for the existence of life:

Cosmic Constants

(1) Gravitational force constant

(2) Electromagnetic force constant

(3) Strong nuclear force constant

(4) Weak nuclear force constant

(5) Cosmological constant

Initial Conditions and "Brute Facts"

(6) Initial distribution of mass energy

(7) Ratio of masses for protons and electrons

(8) Velocity of light

(9) Mass excess of neutron over proton

"Local" Planetary Conditions

(10) Steady plate tectonics with right kind of geological interior

(11) Right amount of water in crust

(12) Large moon with right rotation period

(13) Proper concentration of sulfur

(14) Right planetary mass

(15) Near inner edge of circumstellar habitable zone

(16) Low-eccentricity orbit outside spin-orbit and giant planet resonances

(17) A few, large Jupiter-mass planetary neighbors in large circular orbits

(18) Outside spiral arm of galaxy

(19) Near co-rotation circle of galaxy, in circular orbit around galactic ce

(20) Within the galactic habitable zone

(21) During the cosmic habitable age

Effects of Primary Fine-Tuning Parameters

(22) The polarity of the water molecule

EXPLANATION

Cosmic Constants

(1) Gravitational force constant (large scale attractive force, holds people on planets, and holds planets, stars, and galaxies together)—too weak, and planets and stars cannot form; too strong, and stars burn up too quickly.

(2) Electromagnetic force constant (small scale attractive and repulsive force, holds atoms electrons and atomic nuclei together)—If it were much stronger or weaker, we wouldn't have stable chemical bonds.

(3) Strong nuclear force constant (small-scale attractive force, holds nuclei of atoms together, which otherwise repulse each other because of the electromagnetic force)—if it were weaker, the universe would have far fewer stable chemical elements, eliminating several that are essential to life.

(4) Weak nuclear force constant (governs radioactive decay)—if it were much stronger or weaker, life-essential stars could not form.

(These are the four "fundamental forces.")

(5) Cosmological constant (which controls the expansion speed of the universe) refers to the balance of the attractive force of gravity with a hypothesized repulsive force of space observable only at very large size scales. It must be very close to zero, that is, these two forces must be nearly perfectly balanced. To get the right balance, the cosmological constant must be fine-tuned to something like ***1 part in 10^{120}***. If it were just slightly more positive, the universe would fly apart; slightly negative, and the universe would collapse.

As with the cosmological constant, the ratios of the other constants must be fine-tuned *relative to each other*. Since the logically-possible range of strengths of some forces is potentially infinite, to get a handle on the precision of fine-tuning, theorists often think in terms of the *range* of force strengths, with gravity the weakest, and the strong nuclear force the strongest. The strong nuclear force is 10^{40} times stronger than gravity, that is, ten thousand, billion, billion, billion, billion times the strength of gravity. Think of that range as represented by a ruler stretching across the entire observable universe, about 15 billion light years. If we increased the strength of gravity by just **1 part in 10^{34}** of the range of force strengths (the equivalent of moving less than one inch on the universe-long ruler), the universe couldn't have life sustaining planets.

Initial Conditions and "Brute Facts"

(6) Initial Conditions. Besides physical constants, there are initial or boundary conditions, which describe the conditions present at the beginning of the universe. Initial conditions are independent of the physical constants. One way of summarizing the initial conditions is to speak of the extremely low entropy (that is, a highly ordered) initial state of the universe. This refers to the initial distribution of mass energy. In *The Road to Reality*, physicist Roger Penrose estimates that the odds of the initial low entropy state of our universe occurring by chance alone are on the order of ***1 in $10^{10(123)}$***. This ratio is vastly beyond our powers of comprehension. Since we know a life-bearing universe is intrinsically interesting, this ratio should be more than enough to raise the question: Why does such a universe exist? If someone is unmoved by this ratio, then they probably won't be persuaded by additional examples of fine-tuning.

In addition to initial conditions, there are a number of other, well-known features about the universe that are apparently just brute facts. And these too exhibit a high degree of fine-tuning. Among the fine-tuned (apparently) "brute facts" of nature are the following:

(7) Ratio of masses for protons and electrons—If it were slightly different, building blocks for life such as DNA could not be formed.

(8) Velocity of light—If it were larger, stars would be too luminous. If it were smaller, stars would not be luminous enough.

(9) Mass excess of neutron over proton—if it were greater, there would be too few heavy elements for life. If it were smaller, stars would quickly collapse as neutron stars or black holes.

"Local" Planetary Conditions

But even in a universe fine-tuned at the cosmic level, local conditions can still vary dramatically. As it happens, even in this fine-tuned universe, the vast majority of locations in the universe are unsuited for life. In *The Privileged Planet*, Guillermo Gonzalez and Jay Richards identify 12 broad, widely recognized fine-tuning factors required to build a single, habitable planet. **All 12 factors can be found together in the Earth.** There are probably many more such factors. In fact, most of these factors could be split out to make sub-factors, since each of them contributes in multiple ways to a planet's habitability.

(10) Steady plate tectonics with right kind of geological interior (which allows the carbon cycle and generates a protective magnetic field). If the Earth's crust were significantly thicker, plate tectonic recycling could not take place.

(11) Right amount of water in crust (which provides the universal solvent for life).

(12) Large moon with right planetary rotation period (which stabilizes a planet's tilt and contributes to tides). In the case of the Earth, the gravitational pull of its moon stabilizes the angle of its axis at a nearly constant 23.5 degrees. This ensures relatively temperate seasonal changes, and the only climate in the solar system mild enough to sustain complex living organisms.

(13) Proper concentration of sulfur (which is necessary for important biological processes).

(14) Right planetary mass (which allows a planet to retain the right type and right thickness of atmosphere). If the Earth were smaller, its magnetic field would be weaker, allowing the solar wind to strip away our atmosphere, slowly transforming our planet into a dead, barren world much like Mars.

(15) Near inner edge of circumstellar habitable zone (which allows a planet to maintain the right amount of liquid water on the surface). If the Earth were just 5% closer to the Sun, it would be subject to the same fate as Venus, a runaway greenhouse effect, with temperatures rising to nearly 900 degrees Fahrenheit. Conversely, if the Earth were about 20% farther from the Sun, it would experience runaway glaciations of the kind that has left Mars sterile.

(16) Low-eccentricity orbit outside spin-orbit and giant planet resonances (which allows a planet to maintain a safe orbit over a long period of time).

(17) A few, large Jupiter-mass planetary neighbors in large circular orbits (which protects the habitable zone from too many comet bombardments). If the Earth were not protected by the gravitational pulls of Jupiter and Saturn, it would be far more susceptible to collisions with devastating comets that would cause mass extinctions. As it is, the larger planets in our solar system provide significant protection to the Earth from the most dangerous comets.

(18) Outside spiral arm of galaxy (which allows a planet to stay safely away from supernovae).

(19) Near co-rotation circle of galaxy, in circular orbit around galactic center (which enables a planet to avoid traversing dangerous parts of the galaxy).

(20) Within the galactic habitable zone (which allows a planet to have access to heavy elements while being safely away from the dangerous galactic center).

(21) During the cosmic habitable age (when heavy elements and active stars exist without too high a concentration of dangerous radiation events).

This is a very basic list of "ingredients" for building a single, habitable planet. At the moment, we have only rough probabilities for most of these items. For instance, we know that less than ten percent of stars even in the Milky Way Galaxy are within the galactic habitable zone. And the likelihood of getting just the right kind of moon by chance is almost certainly very low, though we have no way of calculating just how low. What we can say is that the vast majority of possible locations in the visible universe, even within otherwise habitable galaxies, are incompatible with life.

It's important to distinguish this local "fine-tuning" is different from cosmic fine-tuning. With cosmic fine-tuning, we're comparing the actual universe as a whole with other possible but non-actual universes. And though theorists sometimes postulate multiple universes to try to avoid the embarrassment of a fine-tuned universe, we have no direct evidence that other universes exist. When dealing with our local planetary environment, however, we're comparing it with other known or theoretically possible locations within the actual universe. That means that, given a large enough universe, perhaps you could get these local conditions at least once just by chance (though it would be "chance" tightly constrained by cosmic fine-tuning).

So does that mean that evidence of local fine-tuning is useless for inferring design? No. Gonzalez and Richards argue that we can still discern a purposeful pattern in local fine-tuning. As it happens, the same cosmic and local conditions, which allow complex observers to exist, also provide the best setting, overall, for scientific discovery. So complex observers will find themselves in the best overall setting for observing. You would expect this if the universe were designed for discovery, but not otherwise. So the fine-tuning of physical constants, cosmic initial conditions, and local conditions for habitability, suggests that the universe is designed not only for complex life, but for scientific discovery as well.

Effects of Primary Fine-Tuning Parameters

There are a number of striking *effects* of fine-tuning "downstream" from basic physics that also illustrate just how profoundly fine-tuned our universe is. These "effects" should not be treated as independent parameters (see discussion below). Nevertheless, they do help illustrate the idea of fine-tuning. For instance:

(22) The polarity of the water molecule makes it uniquely fit for life. If it were greater or smaller, its heat of diffusion and vaporization would make it unfit for life. This is the result of higher-level physical constants, and also of various features of subatomic particles.

What About All Those Other Parameters?

In discussing fine-tuned parameters, one can take either a maximal or a minimal approach.

Those who take the maximal approach seek to create as long a list as possible. For instance, one popular Christian apologist listed thirty-four different parameters in one of his early books, and maintains a growing list, which currently has ninety parameters. He also attaches exact probabilities to various "local" factors.

While a long (and growing) list sporting exact probabilities has rhetorical force, it also has a serious downside: many of the parameters in these lists are probably derived from other, more fundamental parameters, so they're not really independent. The rate of supernova explosions, for instance, may simply be a function of some basic laws of nature, and not be a separate instance of fine-tuning. If you're going to legitimately multiply the various parameters to get a low probability, you want to make sure you're not "double booking," that is, listing the same factor twice under different descriptions. Otherwise, the resulting probability will be inaccurate. Moreover, in many cases, we simply don't know the exact probabilities.

To avoid these problems, others take a more conservative approach, and focus mainly on distinct, well-understood, and widely accepted examples of fine-tuning. This is the approach taken here. While there are certainly additional examples of fine-tuning, even this conservative approach provides more than enough cumulative evidence for design. After all, it is *this* evidence that has motivated materialists to construct many universe scenarios to avoid the implications of fine-tuning.

Sources

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