

THE BIO-FRIENDLY UNIVERSE: BY DESIGN?

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Introduction

What does it mean on a human scale for an engineer to design a product? What would it mean on a grand scale to say that the universe is the product of an intelligent designer? And what evidence could support such a claim? What features of the universe suggest that a “home” has been carefully crafted for our benefit? William Paley in his classic *Natural Theology* (1802) provided evidence primarily from the biological sciences for a designed universe, but the strength of his argument for design was limited by the scientific understanding of his time, and was subsequently called into question by Darwin’s theory of evolution. However, discoveries in astronomy and cosmology in the last half of the twentieth century have provided an abundance of evidence that seems to point to a designed universe. My purpose in this chapter is to summarize the evidence from cosmology that suggested our universe is indeed a remarkable habitat, for life in general and complex, conscious life (e.g., human beings) in particular, by design. We live in a very bio-friendly universe as you shall see. But let me begin by clarifying what I mean by design.

How Does an Engineer Design Something?

To elucidate what engineers do when they design products for consumers, let me first give a simple example of how we interact with our world when we guide

physical events to accomplish a purpose. Suppose that I wanted to throw a water balloon from the Leaning Tower of Pisa in Italy to the plaza below, hitting a friend who is walking on the plaza (and hopefully missing other tourists). Using the equations Newton discovered for motion and for gravitational attraction, I could describe the descent of the water balloon to the plaza below with the following simple algebraic relationship:

$$H(t) = h_0 - (G m / 2 r^2) t^2 - v_0 t \quad (1)$$

Here G is a universal constant which gives the strength of the gravitational force of attraction, m and r are the mass of the earth and the radius of the earth respectively, and h_0 and v_0 are the height in the tower from which I shall throw the balloon and the vertical velocity with which I throw the balloon.

With these constants and initial conditions defined, I can then calculate the descent of the water balloon as a function of time. $H(t)$ gives the calculated height of the water balloon as a function of time, t , when I threw it. This equation may be used to guarantee that my balloon arrives at the plaza at just the right time to hit my friend. All I need to do is to determine at what time my strolling friend will be just below me in the plaza, and then I can use equation (1) to determine the initial velocity with which I need to throw the balloon. Just dropping the balloon is also fine – I just set $v_0 = 0$ and solve for the correct time to drop the balloon. The precision with which I must specify the velocity of the thrown balloon depends on the mathematical form of equation 1, the specified values for the universal constant G and the initial condition h_0 . With the simple mathematical form of equation 1 and the actual gravity force constant G and height of the Leaning Tower of Pisa, h_0 , hitting my friend should be a cinch.

The three factors that are essential in predicting the motion of the water balloon illustrate the factors that are generally necessary to provide a purposeful outcome in engineering work: (1) the mathematical form that nature takes (as illustrated by equation (1)); (2) the values of the universal constants (G in equation (1)); and (3) the boundary conditions (which include the height h_0 of the tower from which I throw the balloon and the initial velocity v_0 with which I throw the balloon). The terms m and r may be thought of as additional boundary conditions which are specific to the location of the tower on the surface of the earth (rather than some other location in the universe). The engineer has no control over the laws of nature and the mathematical form that they take. Neither

does the engineer have any control over the universal constants such as the gravity force constant. The engineer can only specify the boundary conditions; for example, as when drawing up blueprints to specify exactly how a device will look when it has been fabricated.

Let me illustrate this design process with the requirements (or boundary conditions) that must be specified when an engineer designs an automobile. The engineer must very carefully prescribe the conditions under which the chemical energy in gasoline is released and converted to torque on the wheels of the car. Each dimension for each engine part is critical for the parts to work together harmoniously. The absolute size and shape of the parts (as distinct from the relative size to fit with each other) depends on the forces to be developed and transmitted, which in turn depends on the weight of the car and the speed it should achieve in service. The weight depends on the size, which in turn depends on the number of passengers plus luggage the car will carry. These factors then determine the size of the cylinders and pistons to be used in the engine and the rate at which gasoline is injected into these cylinders. The brake and suspension systems have to be scaled to fit the weight requirements, as does the specifications for the tires.

Notice how many of the specifications are related to each other, and therefore, cannot be independently specified or assigned. The greater is this interdependence of specified boundary conditions, the more complex and demanding are the design requirements. Small errors in the specification of any of these requirements will produce either a car with very inferior performance, or worse yet, a car that does not function at all.

In the next sections, I want to consider whether our universe has these essential features that we associate with design. I will show that a universe that is bio-friendly (i.e., suitable for conscious life) depends on (1) the mathematical form that nature assumes; (2) the values of the universal constants; and (3) the initial or boundary conditions. While engineers can only fix the boundary conditions, the suitability of the universe as a habitat for life in general and for human beings in particular depends on all three. Thus, we will consider how each of these requirements appears to be essential to create a suitable habitat for life, or a bio-friendly universe.

The Remarkable Mathematical Form Nature Takes

Mathematics – in contrast to mere calculation – is an abstract intellectual activity that began in Greece in the 6th century B.C. Pythagoras was a key figure here, as were his successors; for example, Euclid and Archimedes. Their studies focused especially on geometric objects, like straight lines, circles, ellipses, and conic sections generally (i.e., these curves were created when a cone is intersected by a plane). In the 3rd century B.C., Apollonias of Perga wrote eight monumental volumes devoted to these curves, describing their properties as “miraculous.” Yet it never occurred to these mathematicians that such beautiful abstract forms from mathematics were in fact descriptions of real world phenomena. Imagine the delight of Johannes Kepler (1571–1630) some eighteen centuries later when he discovered that the orbits of planets around the sun conformed to these same beautiful but abstract mathematical forms. Kepler noted,

The chief aim of all investigations of the external world should be to discover the rational order and harmony which has been imposed on it by God and which He revealed to us in the language of mathematics.

Galileo Galilei (1564–1642) observed that “the laws of nature are written by the hand of God in the language of mathematics”. Morris Kline in his book *Mathematics: The Loss of Certainty* (1980) notes that the religious mathematicians of the 16th and 17th century – including Newton, Galileo, Kepler and Copernicus – believed that the universe was orderly and thus described by mathematics because a rational God fashioned it that way. Kline says that these scientist/mathematicians believed that

God had designed the universe, and it was to be expected that all phenomena of nature would follow one master plan. One mind designing a universe would almost surely have employed one set of basic principles to govern all related phenomena.

The incredibly diverse phenomena we see in nature are characterized by a small number of physics laws, each of which assumes such a simple mathematical form. Indeed, they can all be written on one side of one sheet of paper as seen in Table 1.

Physicist Eugene Wigner, in a widely cited paper entitled “The Unreasonable Effectiveness of Mathematics in the Physical Sciences” (*Comm. Pure and Appl. Math.*, 1960) notes that scientists should never take for granted the remarkable,

Table 1. The Fundamental Laws of Nature.

- Mechanics (Hamilton's Equations)

$$p = -\frac{\partial H}{\partial q} \quad q = -\frac{\partial H}{\partial p}$$

- Electrodynamics (Maxwell's Equations)

$$F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu$$

$$\partial_\mu F^{\mu\nu} = j^\nu$$

- Statistical Mechanics (Boltzmann's Equations)

$$S = -k \int f \log f dv$$

$$\frac{dS}{dt} \geq 0$$

- Quantum Mechanics (Schrödinger's Equations)

$$i\hbar|\dot{\psi}\rangle = H|\psi\rangle$$

$$\Delta X \Delta P \geq \frac{\hbar}{2}$$

- General Relativity (Einstein's Equation)

$$G_{\mu\nu} = -8\pi G T_{\mu\nu}$$

even miraculous, effectiveness of mathematics in describing the real world. To quote Wigner,

The enormous usefulness of mathematics is something bordering on the mysterious.... There is no rational explanation for it.... The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve....

Albert Einstein in a letter to a friend (1956, *Lettres a Maurice Solovine*) was struck by the mathematical comprehensibility of the world:

You may find it strange that I consider the comprehensibility of the world to the degree that we may speak of such comprehensibility as a miracle or an eternal mystery. Well, a priori one should expect a chaotic world, which cannot be in any way grasped through thought.... The kind of order created, for example, by Newton's theory of gravity is of quite a different kind. Even if the axioms of the theory are posited by a human being, the success of such an

enterprise presupposes an order in the objective world of a high degree, which one has no a priori right to expect. That is the miracle which grows increasingly persuasive with the increasing development of knowledge.

Newton and his contemporaries along with many modern physicists like Einstein and Wigner considered the remarkable mathematical form which nature assumes to be evidence for the existence of an intelligent first cause or designer. For example, the distinguished Russian physicist Alexander Polykov notes that, "We know that nature is described by the best of all possible mathematics because God created it." Australian astrophysicist Paul Davies says, "The equations of physics have in them incredible simplicity, elegance and beauty. That in itself is sufficient to prove to me that there must be a God who is responsible for these laws and responsible for the universe." Cambridge University cosmologist Stephen Hawking makes the artful, even poetic comment, "What is it that breathes fire into the equations and makes a universe for them to govern?"

Nonetheless, mathematical form alone is insufficient to guarantee that our universe is a suitable habitat for life. The particular mathematical forms of the laws of nature are also critical. For example, it is essential that the mathematical forms provide for stable systems at the atomic and cosmic level. The solutions to Hamilton's equations for non-relativistic Newtonian mechanics and for Einstein's theory of general relativity in Table 1 are unstable for a sun with planets unless the gravitational potential energy is proportional to r^{-1} , a requirement which is only met for a universe like ours with three spatial dimensions.

For the solution to Schrödinger's equation (Table 1) for the hydrogen atom to give stable, bound energy levels, again a universe with three (or fewer) spatial dimensions is required. Maxwell's equations (Table 1) are also only valid for a three-(spatial) dimensional universe. Furthermore, Courant and Hilbert (1962, *Methods of Mathematical Physics*) have found that high-fidelity transmission of electromagnetic or acoustic signals is optimized in our three-dimensional universe: "[O]ur actual physical world, in which acoustic or electromagnetic signals are the basis of communication seems to be singled out among the mathematically conceivable models by simplicity and harmony."

In summary, it is clear that the specific mathematical character of our universe is essential for it to be a suitable habitat for life or a bio-friendly universe. Yet the

reason that nature has this precise mathematical form is problematic from a naturalistic or materialistic worldview. As we shall see in the next section, the particular mathematical forms of our universe are a necessary but not sufficient criteria to provide a bio-friendly universe.

The Mystery of the Cosmological Constants

There are certain universal constants that are an essential part of our mathematical description of the universe. A partial list is found in Table 2 and includes Planck's constant h , the speed of light c , the gravity force constant G , the masses of the proton, electron, and neutron, respectively, the unit charge for the electron and proton, and the weak force, strong nuclear force and electromagnetic coupling constants, and Boltzmann's constant k . Prior to the development of cosmological models beginning in the mid-twentieth century were first developed in the mid-twentieth century, it was naively assumed that the selection of a given set of constants was not critical to the formation of a suitable habitat for life. Subsequent parametric studies using these cosmological models to systematically vary the cosmological constants have shown that relatively small changes in any of the constants produce a dramatically different universe which bio-unfriendly in various ways.

Table 2. Partial List of Universal Constants

- Speed of light $c = 3.0 \times 10^8$ m/s
- Planck's constant $h = 6.63 \times 10^{-34}$ J-s
- Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/oK
- Unit charge $e = 1.6 \times 10^{-19}$ coulombs
- Gravity force constant $G = 6.67 \times 10^{-11}$ N-m/kg²
- Rest masses (in kg)
 - Neutron - 1.69×10^{-27}
 - Electron - 9.11×10^{-31}
 - Proton - 1.67×10^{-27}

A large number of books have appeared in the past twenty years to summarize this surprising feature of our universe, to wit, that the universal constants have to be "fine tuned" to have a universe suitable for life. A partial list of these books includes *The Anthropic Cosmological Principle* by John Barrow and Frank Tipler (1986), *The Accidental Universe* (1982) and *Universes* by John Leslie (1989),

Superforce (1984), *The Cosmic Blueprint* (1988), and *The Mind of God* by Paul Davies, *Cosmic Coincidences* by John Gribbin and Martin Rees (1989), *The Anthropic Principle* by Reinhard Breuer (1991), *Universal Constants in Physics* by Gilles Cohen-Tannoudji (1993), *The Creation Hypothesis* edited by J. P. Moreland (1994) and *Mere Creation* edited by William Dembski (1998), *Our Cosmic Habitat* (2001) by Martin Rees, and *Ultimate Reality* (2003) edited by Barrow, Davies, and Harper. I will illustrate with several examples the "fine tuning" requirements for the various universal constants to give a bio-friendly universe.

Physical Fine Structure Constants – The four forces in nature may each be expressed as dimensionless numbers to allow their relative strengths as they act in nature to be compared. The relative strengths vary by a factor of 10^{41} (10 with forty additional zeros after it), or equivalently by 41 orders of magnitude. Yet modest changes in any of these constants would produce dramatic changes in the universe and render it unsuitable for life. Several examples follow to illustrate the necessary "fine tuning" of the relative magnitudes of the four physical forces in our universe.

The electromagnetic force is 10^{38} times stronger than the gravity force. It is the force of gravity that draws protons together in stars causing them to fuse together with a concurrent release of energy. The electromagnetic force causes them to repel. Because the gravity force is so weak compared to the electromagnetic force, the rate at which stars "burn" by fusion is very slow, allowing the stars to provide a stable source of energy over a very long period of time. If this ratio of strengths had been 10^{32} instead of 10^{38} (i.e., gravity were much stronger), stars would be a billion times less massive and would burn a million times faster.

The frequency distribution of electromagnetic radiation produced by the sun is also critical, as it needs to be tuned to the energies of chemical bonds on earth. If the photons of radiation are too energetic (too much ultraviolet radiation), then chemical bonds are destroyed and molecules are unstable; if the photons are too weak (too much infrared radiation), then chemical reactions will be too sluggish. The radiation produced is dependent on a careful balancing of the electromagnetic force (alpha-E) and the gravity force (alpha-G), with the mathematical relationship including $(\alpha-E)^{12}$, making the specification for the electromagnetic force particularly critical. On the other hand, the chemical bonding energy comes from quantum mechanical calculations that include the

electromagnetic force, the mass of the electron, and Planck's constant. Thus, all of these constants have to be sized relative to each other to give a universe in which radiation is tuned to the necessary chemical reactions that are essential for life.

Another fine tuning coincidence is that the emission spectrum for the sun not only peaks at an energy level which is ideal to facilitate chemical reactions, but it also peaks in the optical window for water. Water is 10^7 times more opaque to ultraviolet and infrared radiation than it is to radiation in the visible spectrum (or what we call light). Since living tissue in general and eyes in particular are composed mainly of water, communication by sight would be impossible were it not for this unique window of light transmission by water being ideally matched to the radiation from the sun. Yet this matching requires carefully prescribing the values of the gravity and electromagnetic force constants as well as Planck's constant and the mass of the electron.

Next consider the strength of the nuclear strong force. The most critical element in nature for the development of life is carbon. Yet, it has become apparent that the abundance of carbon in nature is the result of a very precise balancing of the strong force and the electromagnetic force, which determine the quantum energy levels for nuclei. Only certain energy levels are permitted for nuclei and these may be thought of as steps on a ladder. If the mass-energy for two colliding particles results in a combined mass-energy that is equal to or *slightly less* than a permissible energy level on the quantum "energy ladder", then the two nuclei will readily stick together or fuse on collision, with the energy difference needed to reach the step being supplied by the kinetic energy of the colliding particles. If this mass-energy level for the combined particles is exactly right, or "just so," then the collisions are said to have resonance, which is to say a high efficiency of collisions for fusing the colliding particles.

On the other hand, if the combined mass-energy results in a value that is *slightly higher* than one of the permissible energy levels on "energy ladder," then the particles will simply bounce off of each other rather than sticking together or fusing. In 1956 Fred Hoyle predicted the existence of the unknown resonance energy level for carbon, and he was subsequently proven right. The fusion of helium and beryllium give a mass-energy value that is 4% less than the resonance energy in carbon, which is easily made up by kinetic energy. Equally important was the discovery that the mass-energy for the fusion of carbon with helium was one percent greater than quantum energy level on the "energy

ladder” for oxygen, making this reaction quite unfavorable. Thus, almost all beryllium is converted to carbon, but only a small fraction of the carbon is immediately converted to oxygen. These two results require the specification of the relative strength of the strong force and the electromagnetic force to within approximately one percent, which is truly remarkable given their large absolute values and difference of a factor of 100, as seen in Table 2.

More generally, a two percent increase in the strong force relative to the electromagnetic force leaves the universe with no hydrogen, no long-lived stars which burn hydrogen, and no water (which is a molecule composed of two hydrogen atoms and one oxygen atom), the ultimate solvent for life. A decrease of only five percent in the strong force relative to the electromagnetic force would prevent the formation of deuterons from combinations of protons and neutrons. This would in turn prevent the formation of all the heavier nuclei through fusion of deuterons to form helium, helium fusion with helium to form beryllium, and so forth. Rozental in 1980 estimated that the strong force had to be within 0.8 and 1.2 times its actual strength for there to be deuterons and all elements of atomic weight 4 or more.

If the weak force coupling constant (see Table 2) were slightly larger, neutrons would decay more rapidly, reducing the production of deuterons, and thus, of helium and elements with heavier nuclei. On the other hand, if the weak force coupling constant were slightly weaker, the big-bang would burn almost all of the hydrogen into helium with the ultimate outcome being a universe with little or no hydrogen and many heavier elements instead. This would leave no long-term stars and no hydrogen containing compounds, especially water. Breuer in 1991 noted that the appropriate mix of hydrogen and helium to provide hydrogen containing compounds, long term stars, and heavier elements is approximately seventy-five percent hydrogen and twenty-five percent helium, which is just what we find in our bio-friendly universe.

This is only an illustrative and not an exhaustive list of cosmic coincidences. They clearly demonstrate how the four forces in nature have to be very carefully scaled to give a universe that provides long-term sources of energy and a variety of atomic building blocks necessary for life. Many other examples involving the fine-tuning of these forces are described in the books previously cited. Even so, the fine-tuning of the universe is not confined to these four forces. As it turns out,

the elementary particles as well as other universal constants like the speed of light and the Planck's constant also have to be very precisely specified.

Masses of Elementary Particles and Other Universal Constants—Scientists have been surprising to learn that the masses of the elementary particles must also be very carefully specified relative to each other and also to the forces in nature. For example, Stephen Hawking has noted that the difference in the mass of the neutron and the mass of the proton must be approximately equal to twice the mass of the electron. The mass-energy of the proton is 938.28 MeV, the mass-energy of the electron is 0.51 MeV and the mass-energy of the neutron is 939.57 MeV. If the mass-energy of the proton plus the mass-energy of the electron were not slightly smaller than the mass-energy of the neutron, then electrons would combine with protons to form neutrons, with all atomic structure collapsing, leaving a world of neutrons only.

On the other hand, if this difference were larger, then neutrons would all decay into protons and electrons, leaving a world of hydrogen only, since neutrons are necessary for protons to combine to build heavier nuclei and the associated elements. As things are, the neutron is just heavy enough to ensure that the big-bang yields one neutron to every seven protons, allowing for an abundant supply of hydrogen for star fuel and enough neutrons to build up the heavier elements in the universe. Again, the precise relative values for the masses of these elementary particles are seen to be critical to provide a universe with long-term sources of energy and elemental diversity.

Possibly the most dramatic example of fine-tuning is in the necessary requirements for inflationary cosmology, which will be presented in the next section. Inflationary cosmology was developed to resolve the necessity for a very specific initial condition; namely, the velocity the instant after the big bang. However, inflationary cosmology requires an even more precise specification of another universal constant, translating an initial condition problem into a fine-tuning of a universal constant problem.

How have distinguished cosmologists responded the ubiquitous evidence of necessary fine-tuning to produce a bio-friendly universe? Freeman J. Dyson from Princeton University says,

As we look out into the universe and identify the many accidents of physics and astronomy that have worked to our benefit, it almost seems as if the universe must in some sense have known that we were coming.

Nobel laureate Arno Penzias makes this observation about the enigmatic character of the universe:

Astronomy leads us to a unique event, a universe which was created out of nothing and delicately balanced to provide exactly the conditions required to support life. In the absence of an absurdly-improbable accident, the observations of modern science seem to suggest an underlying, one might say, supernatural plan.

Sir Fred Hoyle, famous British astronomer who early on (1951) argued that the coincidences were just that, coincidences, by 1984 had changed his mind, as is evident from this quotation:

Such properties seem to run through the fabric of the natural world like a thread of happy coincidences. But there are so many odd coincidences essential to life that some explanation seems required to account for them.

The Remarkable Requirements for Initial Conditions

The specific mathematical form that nature takes and the fine-tuning of the various universal constants and masses of elementary particles cannot by themselves account for our bio-friendly universe and life. They are necessary but not sufficient conditions. All this elegant fine-tuning of universal constants could have occurred as described above, and life would still not have occurred if the initial conditions at certain critical points had not been properly set. I want therefore to turn to the initial conditions for the big bang. The most widely recognized initial condition problems arises in big-bang cosmology and in the informational requirements for an abiotic origin of life. I have addressed the origin on life problem in detail in *The Mystery of Life: Reassessing Current Theories*. The initial conditions problems of the big bang have been summarized in a *Scientific American* article (January 1999), which will be highlighted next.

The fundamental boundary value (or initial condition) problem with the big bang is the criticality of the initial velocity. If this velocity is too fast, the matter in the universe expands too quickly and never coalesces into planets, stars, and galaxies. If the initial velocity is too slow, the universe expands only for a short time and then quickly collapses under the influence of gravity. Well-accepted cosmological models tell us that the initial velocity must be specified to a precision of $1/10^{55}$. This requirement seems to overwhelm chance and has been

the impetus for creative alternatives, most recently the new inflationary model of the big bang.

Inflation itself, however, seems to require fine-tuning for it to occur at all and for it to yield irregularities neither too small nor too large for galaxies to form. Early on it was estimated that two components of an expansion-driving cosmological constant must cancel each other with accuracy better than 1 part in 10^{50} . In the *Scientific American* article, the required accuracy was sharpened to 1 part in 10^{123} . Furthermore, the ratio of the gravitational energy to the kinetic energy must equal to 1.00000 with a variation of 1 part in 100,000. Such estimates are being actively researched at the moment and their values may change over time. Nonetheless, it appears that very highly specified boundary conditions will be present in whatever model is finally confirmed for the big-bang origin of the universe.

Multiverses: An explanation for our finely-tuned, bio-friendly universe?

The remarkable degree of fine tuning of universal constants and initial condition that is required to produce a bio-friendly universe such as ours is a conundrum for many scientists who are uncomfortable with its consequential theistic implications. In the face of this conundrum, it has become fashionable to posit that there are an extremely large number of universes, each with different combinations of universal constants and maybe even different physical laws.

The multiverse hypothesis, as it has come to be known, may be supported by two very fashionable branches of science: inflationary cosmology and string/M-theory. Inflationary theory suggests the theoretical possibility of many universes and string theory provides a theoretical support for the possibility that each universe could have a unique set of universal constants. It is important to understand that theoretical predictions of multiple universes, with unique sets of universal constants, based on mathematical models can provide no assurances that all these predicted "worlds" are physically instantiated.

At present it appears to be theoretical impossible to ever be able to observe universes outside our own, rendering the multiverse prediction to be outside the usual bounds of science. Furthermore, experimental evidence for string theory and inflationary theory themselves (quite apart from the multi-verse prediction) has been quite elusive to find, since the basic theories do not lead to experimental

predictions that can be easily made. It is for this reason that the multiverse idea remains quite controversial.

Paul Davies notes that the principle indirect observational support for the multiverse hypothesis comes from the sensitivity of biology to the forms of the laws of physics, the values of the universal constants, and the precise initial conditions--the fine-tuning required for a bio-friendly world. He goes on to say that "human beings find themselves living in an universe that in many respects behaves as it is teleological. Historically, in the absence of direct evidence for other universes, scientists and philosophers felt obliged to assume this is the only universe. Monotheistic theologians argued that bio-friendly is exactly what they would expect because God freely and purposely created it that way.

It seems that as the evidence for a bio-friendly universe by design grows stronger and strong, scientists who are uncomfortable with such a theistic universe feel increasingly compelled to embrace (by faith) the very speculative multiverse alternative, despite the fact that it can never be substantiated directly by experimental observations.

Summary

My initial example of design was a very simple. It involved one physical law, one universal constant, and two initial conditions. These could be prescribed so that my water balloon would arrive on the plaza of the Leaning Tower of Pisa just in time to hit my strolling friend. This is a relatively easy design problem. However, for the universe to have stars which generate elemental diversity, provide long-term sources of energy of a suitable wavelength to facilitate chemical reactions, and satisfy many other requirements for a bio-friendly universe that is a suitable habitat for life, the mathematical form of the laws of nature, the nineteen universal constants, and many initial conditions have to be finely tuned.

Many of these requirements are interrelated. For instance, the initial velocity requirement is related to the strength of the gravity force. With so many distinct and interrelated requirements, it is difficult to imagine how all of these could have "accidentally" happened to be exactly what they needed to be. Because of the many cross constraints, it appears unlikely that there is an alternative set of values for these constants which would "work." Furthermore, the necessary values range over almost forty orders of magnitude (10^{40}), making their

accidentally correct “selection” all the more remarkable. It is quite easy to understand why so many scientists have changed their minds in the past forty years, agreeing that the universe cannot reasonably be explained as a cosmic accident. Evidence for an intelligent designer becomes more compelling the more we understand about our bio-friendly universe.