Cosmythology

Is the universe fine-tuned to produce us?

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Abstract

The latest concoction of the argument from design utilizes the so-called anthropic coincidences to assert that the universe is fine tuned for life. The contention is that a random set of physical constants would have had negligible chance for producing us. Undoubtedly, if the universe were to start again from scratch with random parameters it would not look at all the way it does today. However, it can be shown that the conditions necessary for the evolution of some form of life would have arisen from a wide variation in physical constants.

The physicists are getting things down to the nitty-gritty, they've really just about pared things down to the ultimate details and the last thing they ever expected to happen is happening. God is showing through, They hate it, but they can't do anything about it. Facts are facts. . . . God, the Creator, Maker of Heaven and Earth. He made it, we can now see, in that first instant with such incredible precision that a Swiss watch is just a bunch of little rocks by comparison.

Character in *Roger's Version*
by John Updike[1]

Tuned for Life

Recent developments in modern cosmology ~~has~~ have been seized upon to provide a scientific basis for the notion of intelligent design to the universe. The latest concoction of the argument from design is constructed around the so-called *anthropic coincidences.*[2] Here the claim is made that the values of fundamental constants of nature, and various other parameters of our universe, are incredibly fine-tuned for the production of life--perhaps even human life. This fine tuning is said to be far too unlikely to have been accidental, that the only reasonable conclusion is intelligent design, with human life as the intent.[3]

No doubt the universe would look quite different with the tiniest variation of the basic constants of physics. A slight difference in the strength of gravity, the charge of the electron, or the mass of the neutron and life as we know it would not exist. The human race could not have evolved in a universe with different constants. Those who promote the notion of intelligent design think they have found confirmation in the way the universe seems to be exquisitely balanced on the tip of a needle for the purpose, it seems, of producing us.

As yet no theory, including the currently highly successful *Standard Model* of elementary particles and forces, predicts the values of the fundamental constants of the universe. None is able to specify such basic facts about the universe as why the proton has the mass it does, or why the hydrogen atom has the size it does. In the Standard Model, the basic constants of the universe must still be put in by hand. No known first principle prevents any of these constants from taking on a random value from zero to infinity.

Several physical constants have values that one would not expect from naive arguments of symmetry or ideas about the unity of phenomena. Recent developments in particle physics suggest that all the fundamental forces of nature were unified as a single force in the extremely high energy of the early moments of the big bang. Today the forces are no longer identical and the huge differences between force strengths that we now measure are difficult to explain. For example, the ratio of strength of the electric and gravitational forces in an atom is 10^{39}. That is, gravity and the electromagnetic force differ by 39 orders of magnitude. For later purposes, I will call this large number N_1.

In the nineteenth century, the electric and magnetic forces were found to be different aspects of the same basic electromagnetic force. This unification occurred despite the fact that the magnetic force on a charged particle is normally much smaller than the electric force.

In the 1980s, electromagnetism and the weak nuclear force were found to be different aspects of the same basic *electroweak* force. This also came about in the face of the large difference between force strengths observed in the laboratory. In this and the previous examples, the differences in the observed strengths of unified forces is explained in a natural way. When and if gravity is unified with the other forces, its comparative weakness may be shown to be similarly natural. Or, it may be accidental.

Starting with Hermann Weyl in 1919,[4] many have speculated about the large size of the dimensionless number N_1 and its possible connection with other large numbers in cosmology and microphysics. For example, the ratio of a typical stellar lifetime to the time for light to traverse the radius of a proton is another dimensionless number, $N_2 = 10^{39}$, which is the same order of magnitude as N_1. This was the first of what are now called the anthropic coincidences.

Most physicists greeted the $N_1 = N_2$ "coincidence" with the same Bronx cheer, "pbzzzpht," that they give to new interpretations of quantum mechanics. It seems like nothing more than numerology. Look around at enough numbers and you are bound to find some that appear connected.

However, in 1961, R. Dicke argued that N_1 is necessarily large in order that the lifetime of main sequence stars be sufficient to generate heavy chemical elements such as carbon.[5] Furthermore, N_1 must be of the same order of N_2 in any universe with heavy elements. If the gravitational attraction in stars were comparable in strength to the electric repulsion between protons, stars would collapse long before nuclear processes could build up the chemical elements from the original hydrogen and deuterium (heavy hydrogen). The formation of chemical complexity is only possible in a universe of great age.

Biological life needs time to evolve, a stable source of energy over that time, and raw material from which to build complex structures. That raw material includes carbon and other heavy elements to provide the diversity needed for the building of proficient organic systems. While hydrogen, helium, and lithium were readily synthesized in the first few minutes of the big bang, heavier nuclei did not appear until much later, after they were ~~be~~ synthesized inside stars and released into space upon the explosive demise of these stars. The existence of elements heavier than lithium in our universe depends on what also appears to be highly unlikely coincidences.

Billions of years were needed for stars to form, to burn all their hydrogen fuel while manufacturing heavier elements, and finally to explode as supernovae, spraying their atoms into space. Once in space, these elements cooled and accumulated into planets. Billions of additional years were needed for at least one star to provide a stable output of energy so that one of its planets could develop life.

In a debate on the existence of God held at the University of Hawaii on April 13, 1994, Christian theologian William Lane Craig was asked from the audience how he could believe that human beings have a special place in a universe that is so enormous and so old compared to humankind. His answer was essentially that the universe had to be very big and very old to produce us! Paraphrasing Craig's answer, all the billions and billions of stars and galaxies that spread over billions of light years in billions of years were put there so that the chemistry needed for life and human beings had time to evolve.[6] My response: Why not cockroaches?

The element-synthesizing processes in stars depend sensitively on the properties and abundances of deuterium and helium produced in the early universe. Deuterium would not exist if the neutron-proton mass difference were just slightly different from its actual value. The relative abundances of hydrogen and helium also depend strongly on this parameter.

The hydrogen-helium abundances also require a delicate balance of the relative strengths of the gravitational and weak nuclear interactions. A slightly stronger weak force and the universe would be 100 percent hydrogen, since all the neutrons in the early universe would then have decayed. A slightly weaker weak force and few neutrons would decay before being bound up with protons in helium nuclei where energetics prevent their decay. All the protons would also be bound up, leading to a universe that was 100 percent helium. Neither of these extremes would have allowed for the existence of stars and life based on chemistry.

The electron also enters into the tight-rope-act needed to produce the heavier elements. Because the electron mass is less than the neutron-proton mass difference, a free neutron can decay into a proton, electron and neutrino. If this were not the case, the neutron would be stable and most of the protons and electrons in the early universe would have combined to form neutrons, leaving little hydrogen to act as the main component and fuel of stars. It is also rather convenient that the neutron ~~if~~ is heavier than the proton, but not so much heavier that neutrons cannot be bound in nuclei.

The evolution of life on earth thus depends critically on the relative force strengths and mass differences. With the slightest change of these values, the variety and diversity of the chemical elements would not exist. In their tome *The Anthropic Cosmological Principle,* John D. Barrow and Frank J. Tipler have gone to great length in seeking many similar connections - some quite remarkable, others a bit strained - between the physical parameters of our universe and the formation of complex, low energy material structures.[7]

Carbon appears to be the chemical element best suited to act as the building block for the type of complex molecular systems that develop lifelike qualities. Even today, new materials assembled from carbon atoms exhibit remarkable, unexpected properties, from superconductivity to ferromagnetism. However, it is carbon chauvinism to assume that only carbon life is possible. We can imagine life based on silicon or other elements chemically similar to carbon, but these would still require cooking in stars. Hydrogen, helium, and lithium, which were synthesized in the big bang, are all chemically too simple to be assembled into diverse structures.

Furthermore, it seems like molecular chauvinism to rule out other forms of matter in the universe as building-blocks of complex systems. While atomic nuclei, for example, do not exhibit the diversity and complexity seen in the way atoms assemble into molecular structures, perhaps they might be able to do so in a universe with different properties. Sufficient complexity and long life are probably the only ingredients needed for a universe to have life. Carbon may be unlikely, but as I will show, long life and complexity are not.

Fingers and TOEs

The anthropic coincidences resonate with the mystical notions that human existence is deeply connected to the very nature of the universe. However, from the time of Copernicus, cosmology has been based on the principle that the universe is indifferent to humanity and human concerns. Most physicists are not quite ready to give up on the Copernican principle. They believe it should be possible to derive the values of the fundamental constants of nature from a yet-undiscovered **Theory-of-Everything (TOE)** that arises from a set of principles that operate at the level of subnuclear particles, not biological cells.

It is very unlikely that a direct causal connection will ever be found between fundamental processes that apply at subnuclear scales and the details of complex structures on the macroscopic scale of everyday life. I doubt if any TOE will tell us why we have five toes on each foot, or why the three-toed sloth has (I assume) three. Most of the properties of the macroscopic world were not predetermined by events in the early big bang, but emerged by the processes of chance and natural selection.

As pointed out by Stephen J. Gould, rewinding the tape of evolution and playing it back again would have infinitesimal probability of once again producing *Homo sapiens.*[8] I can conceive the possibility that some or all of the constants of physics also took on the values they did by chance and, like evolution, were not designed by either a Creator or physical law.

The chance that any initially random set of constants would correspond to the set of values they hold in our universe is very small. Cosmologist Roger Penrose has calculated that the probability of our universe is one part in $10^{10^{123}}$. In *The Emperor's New Mind*, Penrose has a cartoon of the Creator pointing a finger toward an "absurdly tiny volume in the phase space of possible universes" to produce the universe in which we live.[9] This has given comfort to believers. In the Hawaii debate mentioned above, theologian Craig argued that this unimaginable low probability illustrates the need for a Creator, that the universe could not have happened by chance. Most of the audience greeted that with enthusiastic nods. Only a few of us sat there with frowns on our faces.

But claiming our universe is a miracle because of its unlikelihood, calculated after the fact, is like the TV ads for publisher sweepstakes that sing “Miracles can happen, can happen to you” if you simply send in your entry. It may seem like a miracle to the person who wins ten million dollars, but the probability was unity that someone would win. It is like calling the sunrise each morning a miracle.

Every human being on earth is the product of a highly elaborate combination of genes that would be a very unlikely outcome of a random toss. Think of what an unlikely being you are, the product of so many chance encounters between your male and female ancestors. What if your great-great-great grandmother had not survived that childhood illness? What of your grandfather had been killed by a stray bullet in the war, before he met your grandmother? Despite all those other possibilities, you still exist. Now if you ask, after the fact, what is the probability for your particular set of genes existing, the answer is one-hundred percent! Certainty!

Similarly, the probability for the universe we live in existing as it does, having the values of the fundamental constants that it has, is not one in $10^{10^{123}}$. It is one-hundred percent! Some universe happened, and it happened to be the one we have.

Still, it is argued that if a universe were created with random values of the physical constants, a universe with no life would have almost certainly been the result. Of course, no one would then be around to talk about it and the fact is we are here and talking about it. Unfortunately, we have no way of talking about it with strict rationality. We do not have enough information, examples of other universes to use as data for drawing reasonable conclusions.

One way to "explain" the anthropic coincidences within the framework of existing knowledge of physics and cosmology is to view our universe as just one of a very large number of mini-universes in an infinite super-universe.[10] Each mini-universe has a different set of constants and physical laws. Some might have life of different form than us, others might have no life at all or something even more complex that we cannot even imagine. Obviously we are in one of those universes with life.

Incidentally, this multi-universe picture is often confused with Hugh Everett's *many-worlds interpretation* of quantum mechanics.[11] They are not at all related.

Several commentators have argued that a many-universes cosmology violates Occam's razor. I beg to differ. The entities that the law of parsimony forbids us from multiplying beyond necessity are theoretical hypotheses, not universes. Though the atomic theory multiplied the number of bodies we consider in solving a thermodynamic problem by 10^{24} or so per gram, it did not violate Occam's razor. It provided for a simpler, more powerful exposition of the rules that were obeyed by thermodynamic systems.

Similarly, if many universes cosmology provides an explanation for the origin of our universe that does not require the highly nonparsimonious introduction of a supernatural element that has heretofore not been required to explain any observations, then that explanation is the more economical.

An infinity of random universes is suggested by the modern inflationary model of the early universe. A quantum fluctuation can produce a tiny, empty region of curved space that will exponentially expand, increasing its energy sufficiently in the process to produce energy equivalent to all the mass of the universe in a mere 10^{-42} second. Cosmologist Andre Linde has proposed that a spacetime "foam" empty of matter and radiation will experience local quantum fluctuations in curvature, forming bubbles of "false vacuum" that individually inflate, as described above, into mini-universes with random characteristics.[12] In this view, our universe is one of those expanding bubbles, the product of a single monkey banging away at the keys of a single word processor.

Toy Universes

I thought it might be fun (and instructive) to see what some of these universes might look like. Of course, other universes may have different physical laws and we have no idea what those laws might be, although we can always speculate. All we really know is our universe and its laws. Even in this case, different values of the constants that go into our familiar equations will lead to universes that do not look a bit like ours.

From the values of just four fundamental constants, the physical properties of matter from the dimensions of atoms to the length of the day and year to the age of main sequence stars can be estimated. Two of these constants are the strengths of the electromagnetic and strong nuclear interactions. The other two are the masses of the electron and proton.

This is not, of course the whole story. Many more constants are needed to fill in the details of our universe. The gross properties of our universe are determined by these four constants, and we can vary them to see what a universe might grossly look like with different values of these constants.

I have written a program, *MonkeyGod*, listed in the Appendix, which the reader is welcome to use. Try your own hand at generating universes. Just choose different values of the four constants and see what happens. While these are really only "toy" universes, the exercise illustrates that there could be many ways to produce a universe old enough to have some form of life.

The program computes the following quantities: the (Bohr) radius and binding energy of the hydrogen atom, the radius of a nucleon (proton or neutron) and its binding energy in a nucleus, the lifetime and mass of a typical star, and the radius, length of day, and length of year for a typical planet.[13] It also computes the numbers N_1 and N_2 mentioned in the main chapter text.

The lifetime and mass of a typical main sequence star sets the scale for the age of a universe populated, in the vicinity of at least once such star, by complex material systems assembled from chemical elements produced in the stars themselves. Thus we can easily determine what a universe will look like if it possesses values of the basic parameters that differ from our own.

The following shows some typical outputs. The strength of the electromagnetic force is given by **alpha** (for greater familiarity, 1/alpha is printed out). The strength of the strong nuclear force is **alpha_s**. Both of these quantities are dimensionless (that is, they have no units). The electron mass is indicated by **me**, the proton mass by **mp**. Both are in kilograms. In the tables below, I have rounded off most of the results since only orders of magnitude are really significant in a calculation of this type. The abbreviation for the units in the answers are standard in any physics text.

First we have the universe we know and love:

1/alpha	**alpha_s**	**mp (kg)**	**me (kg)**
137	.2	1.67e-27	9.11e-31

Bohr radius	=	5.29e-9	cm
Hydrogen binding energy	=	13.6	eV
Nucleon radius	=	1.05e-13	cm
Nucleon binding energy	=	18.76	MeV
Minimum stellar lifetime	=	6.77e+8	yr
Mass of star	=	3.69e+30	kg
Radius of planet	=	5700.	km
Mass of planet	=	5.e+23	kg
Length of day	=	6	hr

Length of year	=	6	days
N1	=	2.2e+39	
N2	=	6.0e+39	

The fact that the day is shown as 6 hours and the year as 6 days should not worry the reader. We have a day on a typical planet of the order of 10 hours and a year of the order of 10 days. Our planet earth may be a bit atypical, with a year of the order of 100 days, but that's only an order of magnitude higher, which is pretty good for these calculations.

The next example has all the constants the same except I have set the proton mass equal to a fundamental constant called *Planck mass,* which is the mass of the smallest possible black hole and is about the only "natural" mass that can be defined:

1/alpha	**alpha_s**	**mp (kg)**	**me (kg)**
137	.2	2.e-8	9.11e-31

Bohr radius	=	5.29e-9	cm
Hydrogen binding energy	=	13.6	eV
Nucleon radius	=	8.79e-33	cm
Nucleon binding energy	=	2.2e+20	MeV
Minimum stellar lifetime	=	6e-1	yr
Mass of star	=	2.6e-8	kg
Radius of planet	=	8.e-21	km
Mass of planet	=	1.7e-29	kg

Length of day	=	1.6e-9	hr
Length of year	=	1.5e+34	days
N1	=	1.8e+20	
N2	=	6.0e+39	

Note how the age of a main sequence star is a fraction of a second, obviously far to small to allow time for the cooking of the heavy elements needed for life. This illustrates that a huge difference between the proton mass and the Planck mass is needed for a long-lived universe.

The final example has all the parameters differing greatly from their values in our universe. Yet a viable, though strange, universe results:

1/alpha	**alpha_s**	**mp (kg)**	**me (kg)**
1000000	.001	1.e-30	1.e-35

Bohr radius	=	3.5	cm
Hydrogen binding energy	=	2.8e-12	eV
Nucleon radius	=	3.5e-8	cm
Nucleon binding energy	=	2.8e-7	MeV
Minimum stellar lifetime	=	2e+14	yr
Mass of star	=	1e+37	kg
Radius of planet	=	3e+13	km
Mass of planet	=	1e+23	kg
Length of day	=	4e+15	hr
Length of year	=	1e+39	days
N1	=	5e+43	

N2 = 5e+39

This universe has atoms that have a diameter of 7 cm, days 10^{15} hours long, and years of 10^{39} of our days. Yet stars live for 10^{14} of our years, which should be long enough to produce the materials of life. And, note that N_1 and N_2 are still in the neighborhood of 10^{40}, which is considered so unlikely in most anthropic arguments.

Fig. 1 shows a scatter plot of N_2 vs. N_1 for 100 universes in which the values of the four parameters were generated randomly from a range five orders of magnitude above and five orders of magnitude below their values in our universe, that is, over a total range of ten orders of magnitude. We see that, over this range of parameter variation, N_1 is at least 10^{33} and N_2 at least 10^{20} in all cases. That is, both are still very large numbers. Although many pairs do not lie exactly on the diagonal $N_1 = N_2$, the coincidence between these two quantities is not so rare.

The distribution of stellar lifetimes for these same 100 universes is shown in Fig. 2. While a few are low, most are clearly high enough to allow time for stellar evolution and heavy element nucleosynthesis. I think it is safe to conclude that the conditions for the appearance of a universe with life are not so improbable as the those authors, enamored by the anthropic principle, would have you think.

Appendix

!MonkeyGod. A True Basic™ program by Victor J. Stenger

```
!OPEN #1: name"monkey.out", create newold
!ERASE #1
    CLEAR
    CLOSE #1
    OPEN #1: screen 0,1,0,1
    WINDOW  #1

DIM p(4),ctrue(4),con$(4)
!Conversion factors.  Basic units S.I.
LET ly=9.4e15
LET eV=1.6e-19
LET GeV=1e9*eV
LET MeV=1e6*eV
LET cm=0.01
LET km=1000
LET hr=3600
LET day=24*hr
LET yr=365*day

!Arbitrary Constants
```

```
LET c=2.99792458e8
LET h=6.626075e-34
LET hb=h/2/pi
LET G=6.67259e-1          ! m^2/kg^2   usual S.I. units

!Set parameter true values and names
LET con$(1)=”1/alpha "
LET ctrue(1)=137
LET con$(2)="alpha-s  "
LET ctrue(2)=0.2
LET con$(3)="mp (kg)  "
LET ctrue(3)=1.67e-27
LET con$(4)="me (kg)  "
LET ctrue(4)=9.11e-31
DO
  !Generate universe
  !Read in parameters.  If zero, use true values.
  FOR i = 1 to 4
     INPUT prompt con$(i): par
     IF par <> 0 then
       LET p(i)=par
     ELSE
       LET p(i)=ctrue(i)
     END IF
```

```
NEXT i

LET alpha=1/p(1)             !Fine structure constant
LET alpha-s=p(2)             !Strong interaction constant
LET mp=p(3)                  !mass of proton in kg
LET me=p(4)                  !mass of electron in kg

PRINT #1: con$(1),con$(2),con$(3),con$(4)
PRINT #1: 1/alpha,alpha-s,mp,me

!Compute properties of universe
LET rb=hb/(alpha*me*c)       !Bohr radius
LET Eb=alpha^2*me*c^2/2      !Hydrogen binding energy
LET rN=hb/(alpha-s*mp*c)     !Nucleon radius
LET EN=alpha-s^2*mp*c^2/2    !Nucleon binding energy
LET alpha-G=G*mp^2/hb/c      !gravitational coupling
!Lifetime and mass of main sequence star
LET tstar=alpha^2/alpha-G*(mp/me)^2*hb/mp/c^2
LET mstar=alpha-G^(-1.5)*mp
!Radius and mass of typical planet
LET Rplanet=sqr(0.1)*2*rB*(me/mp)^.25*(alpha/alpha-G)^.5
LET Mplanet=(0.1)^(1.5)*2*mp*(me/mp)^.75*(alpha/alpha-G)^1.5
!Length of day and year
LET Tday=2*pi*2^1.5*rb/c*(mp/(me*alpha*alpha-G))^0.5
```

```
  LET Tyr=.2*rb/c*(mp/me)^2/alpha^6.5/alpha-G^.125
  !Large numbers
  LET N1=alpha/alpha-G*mp/me
  LET N2=c*tstar/rN

  PRINT #1: "Bohr radius              = ",rb*100,"cm"
  PRINT #1: "Hydrogen binding energy  = ",Eb/eV,"eV"
  PRINT #1: "Nucleon radius           = ",rN*100,"cm"
  PRINT #1: "Nucleon binding energy   = ",EN/MeV,"MeV"
  PRINT #1: "Minimum stellar lifetime = ",tstar/yr,"yr"
  PRINT #1: "Mass of star             = ",mstar,"kg"
  PRINT #1: "Radius of planet         = ",Rplanet/km,"km"
  PRINT #1: "Mass of planet           = ",Mplanet,"kg"
  PRINT #1: "Length of day            = ",Tday/hr,"hr"
  PRINT #1: "Length of year           = ",Tyr/day,"days"
  PRINT #1: "N1                       = ",N1
  PRINT #1: "N2                       = ",N2
LOOP
END
```

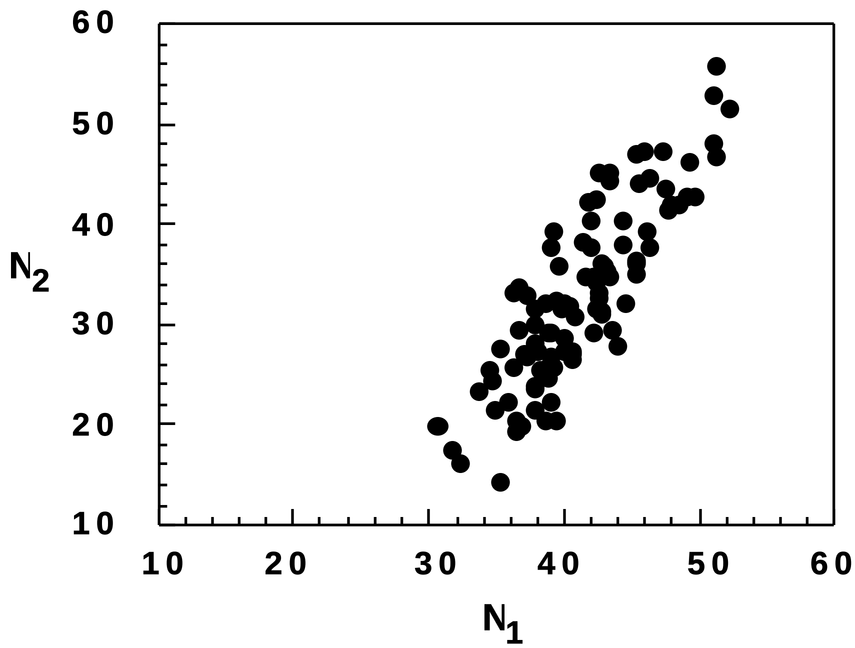

Fig. 1. Plot of N_2 vs N_1 for 100 universes in which the values of the four constants were generated randomly from a range five orders of magnitude above and five orders of magnitude below their values in our universe. We see that, over this range of variation, N_1 is at least 10^{33}, and N_2 is at last 10^{22} in all cases.

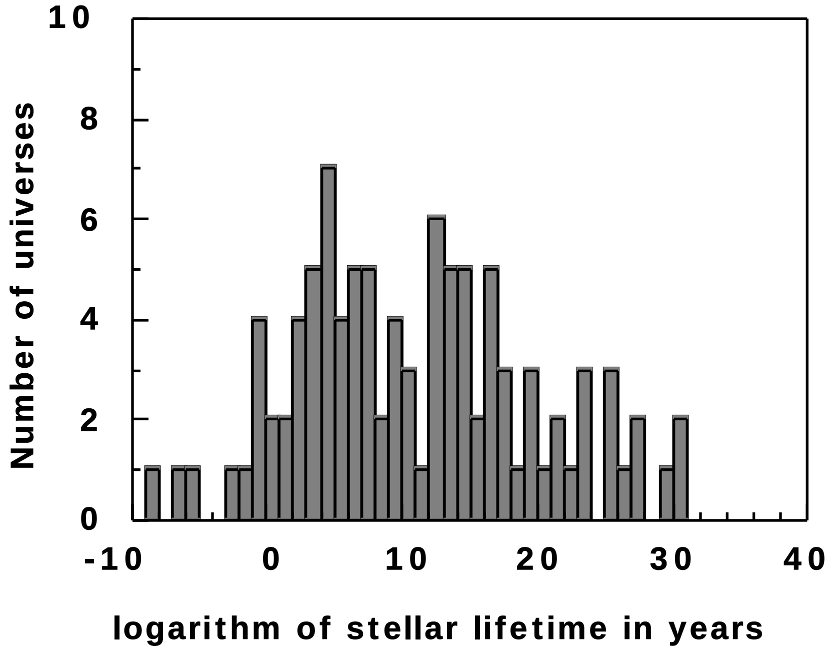

Figure 2 . Distribution of stellar lifetimes for the 100 toy universes described in the text.

Notes

[1] John Updike,*Roger's Version*, New York: Fawcett Crest, pp. 9-10 (1986).

[2] The phrase *anthropic principle* was introduced in Brandon Carter, "Large Number Coincidences and the Anthropic Principle in Cosmology," in M. S. Longair, ed., *Confrontation of Cosmological Theory with Astronomical Data,* Dordrecht: Reidel, 1974, pp. 291-298. See also, B. Carter, *Phil. Trans. Roy. Soc. London* A 310, 347 (1983). For a very complete discussion, see John D. Barrow, and Frank J. Tipler . *The Anthropic Cosmological Principle,* Oxford: Oxford University Press (1986). For popular-level surveys, see P. C. W Davies,*The Accidental Universe.* Cambridge: Cambridge University Press (1982),

and John Gribbon and Martin Rees, *Cosmic Coincidences: Dark Matter, Mankind, and Anthropic Cosmology,* New York: Bantam Books (1989).

[3] Holmes Rolston III, "Shaken Atheism: A Look at the Fine-Tuned Universe," *The Christian Century* , December 3, 1986; Robert Wright, "What Does Science Tell Us About God?"*Time* December 28, 1992, p. 38; Sharon Begley, "Science and the Sacred" *Newsweek* November 28, 1994, p. 56.

[4] H. Weyl, *Ann. Physik* 59, 101 (1919).

[5] R.H. Dicke, "Dirac's Cosmology and Mach's Principle," *Nature* 192, 440 (1961).

[6] For Craig's views on cosmology and theology, see William Lane Craig, "'What place, then, for a creator?': Hawking on God and Creation," *Brit. J. Phil. Sci.* 41, 473-491, (1990) and "The Origin and Creation of the Universe: A Reply to Adolf Grünbaum," *Brit. J. Phil. Sci.* 43, pp. 233-240 (1992).

[7] See Barrow and Tipler, 1986, in ref. 2.

[8] Stephen J.Gould, *Wonderful Life: The Burgess Shale and the Nature of History*, New York: Norton (1989).

[9] Roger Penrose,*The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics.* Oxford: Oxford University Press (1989).

[10] For a recent discussion of this idea, see Andre Linde, "The Self-Reproducing Inflationary Universe." *Scientific American.* November, 1994, pp. 48-55.

[11] Hugh Everett III,*Rev. Mod. Phys.* 29, 454 (1957).

[12] A. D. Linde, *Physics Letters* 108B, 389 (1982); "Particle Physics and Inflationary Cosmology," *Physics Today* 40, 61-68 (1987);*Particle Physics and Inflationary Cosmology*, New York: Academic Press; also, ref, 10. See also David Atkatz, "Quantum Cosmology for Pedestrians." *Am. J. Phys.* 62(7), 619 (1994).

[13] The astronomical quantities were calculated using the formulas of W.H. Press and A.P. Lightman,*Phil. Trans. R. Soc. Lond.* A 310, 323 (1983).