Design and the Anthropic Principle

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Summary

Human existence is possible because the constants of physics and the parameters for the universe and for planet Earth lie within certain highly restricted ranges. John Wheeler and others interpret these amazing "coincidences" as proof that human existence somehow determines the design of the universe. Drawing an illogical parallel with delayed-choice experiments in quantum mechanics, they say that observations by humans influence the design of the universe, not only now, but back to the beginning. Such versions of what is called the "anthropic principle" reflect current philosophical and religious leanings towards the deification of man. They produce no evidence to support the notion that man's present acts can influence past events. Furthermore, their analogies with quantum mechanics break down on this point. The "coincidental" values of the constants of physics and the parameters of the universe point, rather, to a designer who transcends the dimensions and limits of the physical universe.

Cosmic Connection

Now that the limits and parameters of the universe can be calculated, and some even directly measured, astronomers and physicists have begun to recognize a connection between these limits and parameters and the existence of life. It is impossible to imagine a universe containing life in which any one of the fundamental constants of physics or any one of the fundamental parameters of the universe is different, even slightly so, in one way or another.

From this recognition arises the *anthropic principle*—everything about the universe tends toward man, toward making life possible and sustaining it. The first popularizer of the principle American physicist John Wheeler, describes it in this way, "A life-giving factor lies at the centre of the whole machinery and design of the world."[1] Of course, design in the natural world has been acknowledged since the beginning of recorded history. Divine design is the message of each of the several hundred creation accounts that form the basis of the world's religions.[2, 3] The idea that the natural world was designed especially for mankind is the very bedrock of the Greek, as well as of the Judeo-Christian world view. Western philosophers of the post-Roman era went so far as to formalize a discipline called *teleology*—the study of the evidence for overall design and purpose in nature. Teleology attracted such luminaries as Augustine, Maimonides, Aquinas, Newton and Paley, all of whom gave it much of their life's work.

Dirac and Dicke's Coincidences

One of the first to recognize that design may also apply to the gross features of the universe was American physicist Robert Dicke. In 1961 he noted that life is possible in the universe only because of the special relationships among certain cosmological parameters[4] (relationships researched by British physicist Paul Dirac twenty-four years earlier[5]).

Dirac noted that the number of baryons (protons plus neutrons) in the universe is the square of the gravitational constant as well as the square of the age of the universe (both expressed as dimensionless numbers). Dicke discerned that with a slight change in either of these relationships life could not exist. Stars of the right type for sustaining life supportable planets only can occur during a certain range of ages for the universe. Similarly, stars of the right type only can form for a narrow range of values of the gravitational constant.

The Universe as a Fit Habitat

In recent years these and other parameters for the universe have been more sharply defined and analyzed. Now, nearly two dozen coincidences evincing design have been acknowledged:

1. The gravitational coupling constant—i.e., the force of gravity, determines what kinds of stars are possible in the universe. If the gravitational force were slightly stronger, star formation would proceed more efficiently and all Stars would be more massive than our sun by at least 1.4 times. These large stars are important in that they alone manufacture elements heavier than iron, and they alone disperse elements heavier than beryllium to the interstellar medium. Such elements are essential for the formation of planets as well as of living things in any form. However, these Stars burn too rapidly and too unevenly to maintain life-supporting conditions on surrounding planets. Stars as small as our sun are necessary for that.

   On the other hand, if the gravitational force were slightly weaker, all stars would have less than 0.8 times the mass of the sun. Though such stars burn long and evenly enough to maintain life-supporting planets, no heavy elements essential for building such planets or life would exist.

2. The strong nuclear force coupling constant holds together the particles in the nucleus of an atom. If the strong nuclear force were slightly weaker, multi-proton nuclei would not hold together. Hydrogen would be the only element in the universe.

If this force were slightly stronger, not only would hydrogen be rare in the universe, but the supply of the various life-essential elements heavier than iron (elements resulting from the fission of very heavy elements) would be insufficient. Either way, life would be impossible.[a]

3. The weak nuclear force coupling constant affects the behavior of leptons. Leptons form a whole class of elementary particles (e.g. neutrinos, electrons, and photons) that do not participate in strong nuclear reactions. The most familiar weak interaction effect is radioactivity, in particular, the beta decay reaction:

   neutron → proton + electron + neutrino

   The availability of neutrons as the universe cools through temperatures appropriate for nuclear fusion determines the amount of helium produced during the first few minutes of the big bang. If the weak nuclear force coupling constant were slightly larger, neutrons would decay more readily, and therefore would be less available. Hence, little or no helium would be produced from the big bang. Without the necessary helium, heavy elements sufficient for the constructing of life would not be made by the nuclear furnaces inside stars. On the other hand, if this constant were slightly smaller, the big bang would burn most or all of the hydrogen into helium, with a subsequent over-abundance of heavy elements made by stars, and again life would not be possible.

   A second, possibly more delicate, balance occurs for supernovae. It appears that an outward surge of neutrinos determines whether or not a supernova is able to eject its heavy elements into outer space. If the weak nuclear force coupling constant were slightly larger, neutrinos would pass through a supernova's envelop without disturbing it. Hence, the heavy elements produced by the supernova would remain in the core. If the constant were slightly smaller, the neutrinos would not be capable of blowing away the envelop. Again, the heavy elements essential for life would remain trapped forever within the cores of supernovae.

4. The electromagnetic coupling constant binds electrons to protons in atoms. The characteristics of the orbits of electrons about atoms determines to what degree atoms will bond together to form molecules. If the electromagnetic coupling constant were slightly smaller, no electrons would be held in orbits about nuclei. If it were slightly larger, an atom could not "share" an electron orbit with other atoms. Either way,

molecules, and hence life, would be impossible.

5. The ratio of electron to proton mass also determines the characteristics of (he orbits of electrons about nuclei. A proton is 1836 times more massive than an electron. if the electron to proton mass ratio were slightly larger or slightly smaller, again, molecules would not form, and life would be impossible.

6. The age of the universe governs what kinds of stars exist. It takes about three billion years for the first stars to form. It takes another ten or twelve billion years for supernovae to spew out enough heavy elements to make possible stars like our sun, stars capable of spawning rocky planets. Yet another few billion years is necessary for solar-type stars to stabilize sufficiently to support advanced life on any of its planets. Hence, if the universe were just a couple of billion years younger, no environment suitable for life would exist. However, if the universe were about ten (or more) billion years older than it is, there would be no solar-type stars in a stable burning phase in the right part of a galaxy. In other words, the window of time during which life is possible in the universe is relatively narrow.

7. The expansion rate of the universe determines what kinds of stars, if any, form in the universe. If the rate of expansion were slightly less, the whole universe would have recollapsed before any solar-type stars could have settled into a stable burning phase. If the universe were expanding slightly more rapidly, no galaxies (and hence no stars) would condense from the general expansion. How critical is this expansion rate? According to Alan Guth,[6] it must be fine-tuned to an accuracy of one part in 10^{55}. Guth, however, suggests that his inflationary model, given certain values for the four fundamental forces of physics, may provide a natural explanation for the critical expansion rate.

8. The entropy level of the universe affects the condensation of massive systems. The universe contains 100,000,000 photons for every baryon. This makes the universe extremely entropic, i.e. a very efficient radiator and a very poor engine. If the entropy level for the universe were slightly larger, no galactic systems would form (and therefore no stars). If the entropy level were slightly smaller, the galactic systems that formed would effectively trap radiation and prevent any fragmentation of the Systems into stars Either way the universe would be devoid of stars and, thus, of life. (Some models for the universe relate this coincidence to a dependence of entropy upon the gravitational coupling constant.[7, 8].)

9. The mass of the universe (actually mass + energy, since $E = mc^2$) determines how much nuclear burning takes place as the universe cools from the hot big bang. If the mass were slightly larger, too much deuterium (hydrogen atoms with nuclei containing both a proton and a neutron) would form during the cooling of the big bang. Deuterium is a powerful catalyst for subsequent nuclear burning in Stars. This extra deuterium would cause stars to burn much too rapidly to sustain life on any possible planet.

On the other hand, if the mass of the universe were slightly smaller, no helium would be generated during the cooling of the big bang. Without helium, stars cannot produce the heavy elements necessary for life. Thus, we see a reason why the universe is as big as it is. If it were any smaller (or larger), not even one planet like the earth would be possible.

10. The uniformity of the universe determines its stellar components. Our universe has a high degree of uniformity. Such uniformity is considered to arise most probably from a brief period of inflationary expansion near the time of the origin of the universe. If the inflation (or some other mechanism) had not smoothed the universe to the degree we see, the universe would have developed into a plethora of black holes separated by virtually empty space.

On the other hand, if the universe were smoothed beyond this degree, stars, star clusters, and galaxies may never have formed at all. Either way, the resultant universe would be incapable of supporting life.

11. The stability of the proton affects the quantity of matter in the universe and also the radiation level as it pertains to higher life forms. Each proton contains three quarks. Through the agency of other particles (called

bosons) quarks decay into antiquarks, pions, and positive electrons. Currently in our universe this decay process occurs on the average of only once per proton per 10^{32} years.[b] If that rate were greater, the biological consequences for large animals and man would be catastrophic, for the proton decays would deliver lethal doses of radiation.

On the other hand, if the proton were more stable (less easily formed and less likely to decay), less matter would have emerged from events occurring in the first split second of the universe’s existence. There would be insufficient matter in the universe for life to be possible.

12. The fine structure constants relate directly to each of the four fundamental forces of physics (gravitational, electromagnetic, strong nuclear, and weak nuclear). Compared to the coupling constants, the fine structure constants typically yield stricter design constraints for the universe. For example, the electromagnetic fine structure constant affects the opacity of stellar material. (Opacity is the degree to which a material permits radiant energy to pass through). In star formation, gravity pulls material together while thermal motions tend to pull it apart. An increase in the opacity of this material will limit the effect of thermal motions. Hence, smaller clumps of material will be able to overcome the resistance of the thermal motions. If the electromagnetic fine structure constant were slightly larger, all stars would be less than 0.7 times the mass of the sun. If the electromagnetic fine structure constant were slightly smaller, all stars would be more than 1.8 times the mass of the sun.

13. The velocity of light can be expressed in a variety of ways as a function of any one of the fundamental forces of physics or as a function of one of the fine structure constants. Hence, in the case of this constant, too, the slightest change, up or down, would negate any possibility for life in the universe.

14. The ^{8}Be, ^{12}C, and ^{16}O nuclear energy levels affect the manufacture and abundance of elements essential to life. Atomic nuclei exist in various discrete energy levels. A transition from one level to another occurs through the emission or capture of a photon that possesses precisely the energy difference between the two levels. The first coincidence here is that ^{8}Be decays in just 10^{-15} seconds. Because ^{8}Be is so highly unstable, it slows down the fusion process. If it were more stable, fusion of heavier elements would proceed so readily that catastrophic stellar explosions would result. Such explosions would prevent the formation of many heavy elements essential for life. On the other hand, if ^{8}Be were even more unstable, element production beyond ^{8}Be would not occur.

The second coincidence is that ^{12}C happens to have a nuclear energy level very slightly above the sum of the energy levels for ^{8}Be and ^{4}He. Anything other than this precise nuclear energy level for ^{12}C would guarantee insufficient carbon production for life.

The third coincidence is that ^{16}O has exactly the right nuclear energy level either to prevent all the carbon from turning into oxygen or to facilitate sufficient production of ^{16}O for life. Fred Hoyle, who discovered these coincidences in 1953, concluded that “a superintellect has monkeyed with physics, as well as with chemistry and biology.”[10]

15. The distance between stars affects the orbits and even the existence of planets. The average distance between stars in our part of the galaxy is about 30 trillion miles. If this distance were slightly smaller, the gravitational interaction between stars would be so strong as to destabilize planetary orbits. this destabilization would create extreme temperature variations on the planet. If this distance were slightly larger, the heavy element debris thrown out by supernovae would be so thinly distributed that rocky planets like earth would never form. The average distance between stars is just right to make possible a planetary system such as our own.

16. The rate of luminosity increase for stars affects the temperature conditions on surrounding planets. Small stars, like the sun, settle into a stable burning phase once the hydrogen fusion process ignites within their core.

However, during this stable burning phase such stars undergo a very gradual increase in their luminosity. This gradual increase is perfectly suitable for the gradual introduction of life forms, in a sequence from primitive to advanced, upon a planet. If the rate of increase were slightly greater, a runaway green house effect[c] would be fell sometime between the introduction of the primitive and the introduction of the advanced life forms. If the rate of increase were slightly smaller, a runaway freezing[d] of the oceans and lakes would occur. Either way, the planet's temperature would become too extreme for advanced life or even for the long-term survival of primitive life.

This list of sensitive constants is by no means complete. And yet it demonstrates why a growing number of physicists and astronomers have become convinced that the universe was not only divinely brought into existence but also divinely designed. American astronomer George Greenstein expresses his thoughts:

As we survey all the evidence, the thought insistently arises that some supernatural agency—or, rather, Agency—must be involved. Is it possible that suddenly, without intending to, we have stumbled upon scientific proof of the existence of a Supreme Being? Was it God who stepped in and so providentially crafted the cosmos for our benefit?[11]

The Earth as a Fit Habitat

It is not just the universe that bears evidence for design. The earth itself reveals such evidence. Frank Drake, Carl Sagan, and Iosef Shklovsky were among the first astronomers to concede this point when they attempted to estimate the number planets in the universe with environments favorable for the support of life. In the early 1960's they recognized that only a certain kind of star with a planet just the right distance from that star would provide the necessary conditions for life.[12] On this basis they made some rather optimistic estimates for the probability of finding life elsewhere in the universe. Shklovsky and Sagan, for example, claimed that 0.001 percent of all stars could have a planet upon which advanced life resides.[13]

While their analysis was a step in the right direction, it overestimated the range of permissible star types and the range of permissible planetary distances. It also ignored *many* other significant factors. A sample of parameters sensitive for the support of life on a planet are listed in Table 1.

Table 1: Evidence for the design of the sun-earth-moon system[14 - 31]

The following parameters cannot exceed certain limits without disturbing the earth's capacity to support life. Some of these parameters are more narrowly confining than others. For example, the first parameter would eliminate only half the stars from candidacy for life-supporting Systems, whereas parameters five, seven, and eight would each eliminate more than ninety-nine in a hundred star-planet systems. Not only must the parameters for life support fall within a certain restrictive range, but they must remain relatively constant over time. And we know that several, such as parameters fourteen through nineteen, are subject to potentially catastrophic fluctuation. In addition to the parameters listed here, there are others, such as the eccentricity of a planet's orbit, that have an upper (or a lower) limit only.

1. number of star companions

- *if more than one:* tidal interactions would disrupt planetary orbits
- *if less than one:* not enough heat produced for life

2. parent star birth date

- *if more recent:* star would not yet have reached stable burning phase
- *if less recent:* stellar system would not yet contain enough heavy elements

3. parent star age

- *if older:* luminosity of star would not he sufficiently stable
- *if younger:* luminosity of star would not be sufficiently stable

4. parent star distance from center of galaxy

- *if greater:* not enough heavy elements to make rocky planets

- *if less:* stellar density and radiation would he too great

5. parent star mass

- *if greater:* luminosity output from the star would not be sufficiently stable
- *if less:* range of distances appropriate for life would be too narrow; tidal forces would disrupt the rotational period for a planet of the right distance

6. parent star color

- *if redder:* insufficient photosynthetic response
- *if bluer:* insufficient photosynthetic response

7. surface gravity

- *if stronger:* planet's atmosphere would retain huge amounts of ammonia and methane
- *if weaker:* planet's atmosphere would lose too much water

8. distance from parent star

- *if farther away:* too cool for a stable water cycle
- *if closer:* too warm for a stable water cycle

9. thickness of crust

- *if thicker:* too much oxygen would he transferred from the atmosphere to the crust
- *if thinner:* volcanic and tectonic activity would be too great

10. rotation period

- *if longer:* diurnal temperature differences would he too great
- *if shorter:* atmospheric wind velocities would he too great

11. gravitational interaction with a moon

- *if greater:* tidal effects on the oceans, atmosphere, and rotational period would he too severe
- *if less:* earth's orbital obliquity would change too much causing climatic instabilities

12. magnetic field

- *if stronger:* electromagnetic storms would be too severe
- *if weaker:* no protection from solar wind particles

13. axial tilt

- *if greater:* surface temperature differences would be too great
- *if less:* surface temperature differences would he too great

14. albedo (ratio of reflected light to total amount falling on surface)

- *if greater:* runaway ice age would develop
- *if less:* runaway greenhouse effect would develop

15. oxygen to nitrogen ratio in atmosphere

- *if larger:* life functions would proceed too quickly
- *if smaller:* life functions would proceed too slowly

16. carbon dioxide and water vapor levels in atmosphere

- *if greater:* runaway greenhouse effect would develop
- *if less:* insufficient greenhouse effect

17. ozone level in atmosphere

- *if greater:* surface temperatures would become too low

- *if less:* surface temperatures would he too high; too much uv radiation at surface

18. atmospheric electric discharge rate

- *if greater:* too much fire destruction
- *if less:* too little nitrogen fixing in the soil

19. seismic activity

- *if greater:* destruction of too many life-forms
- *if less:* nutrients on ocean floors would not be uplifted

About a dozen other parameters, such as atmospheric chemical composition, currently are being researched for their sensitivity in the support of life. However, the nineteen listed in Table 1 in themselves lead safely to the conclusion that much fewer than a trillionth of a trillionth of a percent of all stars will have a planet capable of sustaining life. Considering that the universe contains only about a trillion galaxies, each averaging a hundred billion stars,[e] we can see that not even one planet would be expected, by natural processes alone, to possess the necessary conditions to sustain life.[f] No wonder Robert Rood and James Trefil[14] and others have surmised that intelligent physical life exists only on the earth. It seems abundantly clear that the earth, too, in addition to the universe, has experienced divine design.

Man the Creator?

The growing evidence of design would seem to provide further convincing support for the belief that the Creator-God of the Bible formed the universe and the earth. Even Paul Davies concedes that "the impression of design is overwhelming."[32] There must exist a designer. Yet, for whatever reasons, a few astrophysicists still battle the conclusion. Perhaps the designer is not God. But, if the designer is not God, who is? The alternative, some suggest, is man himself.

The evidence proffered for man as the creator comes from an analogy to delayed choice experiments in quantum mechanics. In such experiments it appears that the observer can influence the outcome of quantum mechanical events. With every quantum particle there is an associated wave. This wave represents the probability of finding the particle at a particular point in space. Before the particle is detected there is no specific knowledge of its location—only a probability of where it might be. But, once the particle has been detected, its exact location is known. in this sense, the act of observation is said by some to give reality to the particle. What is true for a quantum particle, they continue, may be true for the universe at large.

American physicist John Wheeler sees the universe as a gigantic feed-back loop.

The Universe [capitalized in the original] starts small at the big bang, grows in size, gives rise to life and observers and observing equipment. The observing equipment, in turn, through the elementary quantum processes that terminate on it, takes part in giving tangible "reality" to events that occurred long before there was any life anywhere.[33]

In other words, the universe creates man, but man through his observations of the universe brings the universe into real existence. George Greenstein is more direct in positing that "the universe brought forth life in order to exist ... that the very cosmos does not exist unless observed."[34] Here we find a reflection of the question debated in freshmen philosophy classes across the land:

If a tree falls in the forest, and no one is there to see it or hear it, does it really fall?

Quantum mechanics merely shows us that in the micro world of particle physics man is limited in his ability to measure quantum effects. Since quantum entities at any moment have the potential or possibility of behaving either as particles or waves, it is impossible, for example, to accurately measure both the position and the momentum of a quantum entity (the Heisenberg uncertainty principle). By choosing to determine the position of the entity the human observer has thereby lost information about its momentum.

It is not that the observer gives "reality" to the entity, but rather the observer chooses what aspect of the reality of the entity he wishes to discern. It is not that the Heisenberg uncertainty principle disproves the principle of causality, but simply that the causality is hidden from human investigation. The cause of the quantum effect is *not* lacking, *nor* is it mysteriously linked to the human observation of the effect after the fact.[g]

This misapplication of Heisenberg's uncertainty principle is but one defect in but one version of the new "observer-as-creator" propositions derived from quantum physics. Some other flaws are summarized here:

> Quantum mechanical limitations apply only to micro, not macro, systems. The relative uncertainty approaches zero as the number of quantum particles in the system increases. Therefore, what is true for a quantum particle would not be true for the universe at large.
>
> The time separation between a quantum event and its observed result is always a relatively short one (at least for the analogies under discussion). A multi-billion year time separation far from fits the picture.
>
> The arrow of time has never been observed to reverse, nor do we see any traces of a reversal beyond the scope of our observations. Time and causality move inexorably forward. Therefore, to suggest that human activity now somehow can affect events billions of years in the past is nothing short of absurd.
>
> Intelligence, or personality, is not a factor in the observation of quantum mechanical events. Photographic plates, for example, are perfectly capable of performing observations.

Both relativity and the gauge theory of quantum mechanics, now established beyond reasonable question by experimental evidence,[37] state that the correct description of nature is that in which the human observer is irrelevant.

Science has yet to produce a shred of evidence to support the notion that man created his universe.

Universe Becoming God?

In *The Anthropic Cosmological Principle,* British astronomer John Barrow and American mathematical physicist Frank Tipler,[38] begin by reviewing evidences for design of the universe, then go on to address several radical versions of the anthropic principle, including Wheeler's feed-back loop connection between mankind and the universe. Referring to such theories as PAP (participatory anthropic principle), they propose, instead, FAP (final anthropic principle).

In their FAP, the life that is now in the universe (and, according to PAP, created the universe) will continue to evolve until it reaches a state of totality that they call the Omega Point. At the Omega Point

Life will have gained control of all matter and forces not only in a single universe, but in all universes whose existence is logically possible; life will have spread into all spatial regions in all universes which could logically exist, and will have stored an infinite amount of information including all bits of knowledge which it is logically possible to know.[39]

In a footnote they declare that "the totality of life at the Omega Point is omnipotent, omnipresent, and omniscient!"[40] Let me translate: the universe created man, man created the universe, and together the universe and man in the end will become the Almighty transcendent Creator. Martin Gardner gives this evaluation of their idea:

What should one make of this quartet of WAP, SAP, PAP, and FAP? In my not so humble opinion I think the last principle is best called CRAP, the Completely Ridiculous Anthropic Principle.[41]

In their persistent rejection of an eternal transcendent Creator, cosmologists seem to be resorting to more and more absurd alternatives. An exhortation from the Bible is appropriate, "See to it that no one takes you captive through hollow and deceptive philosophy."42

Insufficient Universe

It is clear that man is too limited to have created the universe. But, it is also evident that the universe is too limited to have created man. The universe contains no more than 10^{80} baryons[h] and has been in existence for no more than 10^{18} seconds.

Compared to the inorganic systems comprising the universe, biological systems are enormously complex. The genome (complete set of chromosomes necessary for reproduction) of an *E. coli* bacterium has the equivalent of about two million nucleotides. A single human cell contains the equivalent of about six billion nucleotides. Moreover, unlike inorganic systems, the *sequence* in which the individual components are assembled is critical for the survival of biological systems. Also, only amino acids with left handed configurations can be used in protein synthesis, the amino acids can be joined only by peptide bonds, each amino acid first must be activated by a specific enzyme, and multiple special enzymes (enzymes themselves are enormously complex sequence-critical molecules) are required to bind messenger RNA to ribosomes before protein synthesis can begin or end.

The bottom line is that the universe is at least ten billion orders of magnitude (a factor of $10^{10,000,000,000}$ times) too small or too young for life to have assembled itself by natural processes.[i] These kinds of calculations have been done by researchers, both non-theists and theists, in a variety of disciplines.[43-58]

Invoking other universes cannot solve the problem. All such models require that the additional universes remain totally out of contact with one another, that is, their space-time manifolds cannot overlap. The only explanation left to us to tell how living organisms received their highly complex and ordered configurations is that an intelligent, transcendent Creator personally infused this information.

An intelligent, transcendent Creator must have brought the universe into existence. An intelligent, transcendent Creator must have designed the universe. An intelligent, transcendent Creator must have designed planet Earth. An intelligent, transcendent Creator must have designed life.

FOOTNOTES:

a. The strong nuclear force is actually much more delicately balanced. An increase as small as two percent means that protons would never form from quarks (particles that form the building blocks of baryons and mesons). A similar decrease means that certain heavy elements essential for life would be unstable.

b. Direct observations of proton decay have yet to be confirmed. Experiments simply reveal that the average proton lifetime must exceed 10^{32} years.[9] However, if the average proton lifetime exceeds about 10^{34} years, than there would be no physical means for generating the matter that is observed in the universe.

c. An example of the greenhouse effect is a locked car parked in the sun. Visible light from the sun passes easily through the windows of the car, is absorbed by the interior, and reradiated as infrared light. But, the windows will not permit the passage of infrared radiation. Hence, heat accumulates in the car’s interior. Carbon dioxide in the atmosphere works like the windows of a car. The early earth had much more carbon dioxide in its atmosphere. However, the first plants extracted this carbon dioxide and released oxygen. Hence, the increase in the sun’s luminosity was balanced off by the decrease in the greenhouse effect caused by the lessened amount of carbon dioxide In the atmosphere.

d. A runaway freezing would occur because snow and ice reflect better than other materials on the surface of the earth. Less solar energy is absorbed thereby lowering the surface temperature which in turn creates more snow and ice.

e. The average number of planets per star is still largely unknown. The latest research suggests that only bachelor stars with characteristics similar to those of the sun may possess planets. Regardless, all researchers agree that the figure is certainly much less than one planet per star.

f. The assumption is that all life is based on carbon. Silicon and boron at one time were considered candidates for alternate life chemistries. However, silicon can sustain amino acid chains no more than a hundred such molecules long. Boron allows a little more complexity but has the disadvantage of not being very abundant in the universe.

g. One can easily get the impression from the physics literature that the Copenhagen interpretation of quantum mechanics is the only accepted philosophical explanation of what is going on in the micro world. According to this school of thought, “1) There is no reality in the absence of observation; 2) Observation creates reality.” In addition to the Copenhagen interpretation physicist Nick Herbert outlines and critiques six different philosophical models for interpreting quantum events.[35] Physicist and theologian Stanley Jaki outlines yet an eighth model.[36] While a clear philosophical understanding of quantum reality is not yet agreed upon. physicists do agree on the results one expects from quantum events.

h. Baryons are protons and other fundamental particles, such as neutrons, that decay into protons.

i. A common rebuttal is that not all amino acids in organic molecules must be strictly sequenced. One can destroy or randomly replace about 1 amino acid out of 100 without doing damage to the function of the molecule. This is vital since life necessarily exists in a sequence—disrupting radiation environment. However, this is equivalent to writing a computer program that will tolerate the destruction of 1 statement of code out of 1001. In other words, this error-handling ability of organic molecules constitutes a far more unlikely occurrence than strictly sequenced molecules.

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