Non-probabilistic Approach to Anthropic Principle and a Fallacy of the Fine-Tuning Argument

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Although it is now seldom discussed by scientists themselves, the creed of science is essentially Neoplatonic. The primary assumption of natural sciences is that world events occur according to rules which scientists call the Laws of Nature. These rules are thought to be independent of our will and the aim of science is to obtain a knowledge of these laws. Knowledge of the laws of nature enables us to predict future events—and also to reconstruct the events of the past. Belief in natural laws underlies everything that natural scientists do and is *implicitly* contained in every physics textbook. Even when scientists become equivocal about this, their actions speak louder than their words.

According to this view space and time together with their material content do not govern themselves; their behavior and fate is determined by a system of laws which are themselves atemporal and all encompassing. In other words, the laws are *universal*; the world changes, but the laws do not. If it were otherwise, science would have no predictive power. One can say that the laws constitute a logical structure for constantly changing world events which is tantamount to maintaining that it is ruled by Reason or Logos.

The very idea of natural laws—without which science would not exist—was conceived in the religious society centered on the ancient Greek philosopher and sage Pythagoras. These ideas were later developed by Plato and Aristotle. The founder of modern European science Isaac Newton was deeply influenced by the Christian Neoplatonism.

The following statements, the first by Albert Einstein and the second by the famous British philosopher and mathematician Alfred North Whitehead, illustrate our point[1].

> …ultimately the belief in the existence of fundamental all-embracing laws also rests on a sort of faith. All the same, this faith has been largely justified by the success of science. On the other hand, however, everyone who is seriously engaged in the pursuit of science becomes convinced that the laws of nature manifest the existence of a spirit vastly superior to that of men, and one in the face of which we with our modest powers must feel humble (Einstein to Phyllis Wright, 24 January 1936, quoted in Jammer 2002, 93).

> In the first place, there can be no living science unless there is a widespread instinctive conviction in the existence of an *Order Of Things*, and, in particular, of an *Order Of Nature* . . .

> …the inexpugnable belief that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner . . . must come from the medieval insistence on the rationality of God . . .

> …My explanation is that the faith in the possibility of science, generated antecedently to the development of modern scientific theory, is an unconscious derivative from medieval theology (Whitehead 1967 [1925], 3–4, 12–13).

This governing *logical structure* constitutes its own realm, by virtue of having a status different from that of the events. The Laws of Nature are not located at any particular point in time or space. They are not things or events, but they direct events and therefore one may speak with confidence about their preexistence and independence of the material content of the Universe. We deduce this structure from the observation of the phenomena—not seeing it with our eyes or hearing it with our ears, but deducing it through our intelligence by means of hypothesis and analysis. The proper analogy for the relationship of the natural laws to matter would be that of the blueprint to the building or software to hardware.

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[1] As far as contemporary scientists are concerned a compelling exposition of this point of view is given in the introduction to Penrose, Roger. 2005. *The Road to Reality*.

The laws are "out there" in the sense that they are not our invention, nor are they social constructs, although our knowledge of them is necessarily limited and changes with time. No self-respecting scientist would say that he or she has invented some natural law; laws are not invented, but discovered, just as Columbus discovered America for Europeans, although it had been there all the time, long before his voyage. Just as Columbus mistook America for India because his theory was wrong, we can also be confused about the real meaning of our discoveries; but our understanding is improved through a continuing process of criticism, verification, and argument.

For us, human beings, a relation between us and this heavenly realm of Laws is of the principal interest. Are these laws originated from an agency indifferent to us or designed to facilitate a formation of life and intelligence? What is a relation between human intelligence and the One which has been and is forming the Cosmos? In other words, is there any affinity between Logos and Nous (Nouz)? The current advanced state of knowledge allows us to address these problems with greater confidence than ever before.

The discoveries of the last fifty years have greatly clarified our understanding of cosmogenesis. We view it as a process of increasing detalization; the Universe has been proceeding from a structureless and highly uniform state to the current state where it is populated by a diverse variety of structures of various degree of complexity from the elementary particles to human brains. In this process the more complex structures always appear after and from simpler ones and their existence is contingent on the stability of the previous level of complexity. The newborn Universe is filled with a hot soup of elementary particles, they first assemble into hydrogen and helium nuclei, then first neutral atoms emerge, the Universe became transparent for light, first stars form from the hydrogen gas, elements heavier than hydrogen form in the stars, stars age and explode throwing around heavy elements, planets form, complex molecules form in space and on planets, ever more complex molecules emerge, then comes primitive life, ever more complex life forms are produced and at last comes the most complex creatures we know – humans.

In the following pages I will discuss the aspects of the natural laws which allow and enable an uninterrupted process of increase of complexity leading from elementary particles to DNA molecules, single-cell and multicellular organisms and eventually to humans. It is widely recognized now that the existence of such process cannot be taken for granted, that the very possibility to build more complicated structures from simple ones imposes strict conditions on the natural laws. I will argue that this fact points to deliberate design.

The problematic I am going to discuss below is directly related to the so-called Anthropic Principle (AP). In general terms, AP states that humans occupy a privileged position in the Universe. Originally this principle was put forward to give scientific justification to the old religious idea. However, in the course of heated philosophical and ideological debates, AP has lost any definitive form; and now groups with quite different metaphysical views adhere to its two main versions, called Strong and Weak AP. Depending on how one understands AP, it seems like either a perfect banality or a great intellectual achievement.

Strong AP is stated by Barrow and Tipler (1986, 21) as follows:

> The Universe must have those properties which allow life to develop within it at some stage in its history.

In what follows, however, I am going to be using a different formulation which is closer to the Discoverability Principle proposed by Alexei and Lev Burov (2016, 2016–2017), namely:

> The Universe is designed not only to be inhabited by intelligent beings, but, much more, to be cosmically cognited by them. (Moira and Eileithyia for Genesis, 2016)

Thus Strong AP uses science to support the idea that the Universe is designed with a special purpose.

Weak AP, in contrast, states that:

> The features of physical laws beneficial to the appearance of Homo sapiens are the result of a self-selection process akin to Darwinian evolution: physical laws are life-friendly because otherwise there would be nobody to discover them. (Cf. Barrow and Tipler 1986, 16, 19)

Normally, adherents of Weak AP assume an infinite or very large number of universes (the multiverse), each of them endowed with different laws of nature. Since the Universe we know is governed by the same laws of physics everywhere, the multiverse assumption is logically necessary to hold the Weak AP as an explanation of life-friendliness of the laws of nature.

Adherents of both forms of AP admit that the appearance of life in general and *Homo sapiens* in particular is conditional on the special properties of the laws of physics. The modern cosmology considers the Universe as an evolving entity in which more complex systems build upon and appear later than simpler ones. The bodies of intelligent creatures are the most complex material systems known, and they emerge at the latest stage of evolution. Therefore, the laws of physics must facilitate the uninterrupted process of emergence of ever more complex forms where every new step is *conditional* on the existence and stability of previous structures. Most discussions of AP revolve around this aspect of the problem. However, in my opinion, this unduly narrows the discussion; this is why I decided to use the rephrased formulation of Strong AP.

Opposite processes in cosmogenesis. In cosmogenesis one can clearly see two processes: the process of emergence of ever more complex forms and the process of degeneration, of irretrievable loss, described by physicists as a process of increasing entropy. The new-born universe is structureless and uniform; its entropy is low due to its incredible uniformity. All material processes proceed due to this low entropy and on its expense since it increases all the time. However, it did not increase uniformly in all parts of our world. Every creation of complex structures is accompanied by a decrease in local entropy for which one has to pay by its rise elsewhere. The most striking example of this is emergence of life, which continuously creates new order locally, but increases disorder (entropy) in its environment. It is clear therefore that life is in some sense “unnatural”, very special, it runs contrary to some universal tendency, tendency for destruction and decay and hence requires an explanation.

Fragility of complex structures. Complexity is a necessary condition for life, whether it is based on carbon or anything else. The more complex the structure, the more fragile it is, and the harder it is to find for it a place in the universe. To break the atomic nucleus, one needs a temperature of millions of degrees, which exists only inside of stars; to detach electrons from the nuclei thousands degrees are sufficient, to break complex molecules one needs only hundreds of degrees (the conditions in boiling water). With emergence of protein-based life the complexity is taken several orders of magnitude higher than complexity of structures of inanimate matter. Biosphere exists inside of the geosphere and its existence is possible only in a narrow range of temperatures. In our solar system such conditions exist only on Earth and perhaps in the oceans of some of Jupiter's moons. Hence it is clear that the emergence of complex structures cannot be considered as a matter of course, that this cosmological process, like a stretched string, is always ready to break. Boris Pasternak wrote:

> "You see, the course of the centuries is like a parable
> *And can be stopped on the go. "*

The book "The Anthropic Cosmological Principle" by two British physicists John Barrow and Frank Tipler lists various interesting coincidences, preparing the conditions for the emergence of life. This book explains how subtle is the balance of forces holding the complex system from disintegration. More than that: the book shows how to express these apparent coincidences mathematically in the form of mathematical equations on physical constants that make up the laws of nature. Thus conditions for a possibility of life as we know it can be expressed as conditions of existence of solutions of this system of equations.

Stephen Hawking wrote in his book "A Brief History of Time": "scientific laws in the form known to us it today, include a number of fundamental numbers such as the value of the electron charge [the fine structure constant " alpha ". See below - *A .Ts*.], the ratio of proton and electron masses ... it is remarkable that the numerical values of these quantities are accurately matched in order to make the development of life possible. "

In order to understand what Barrow, Tipler and Hawking mean we need to know what is meant by the fundamental numbers (in physics they are usually called dimensionless constants). Below I will give a brief explanation followed by a detailed example.

Laws of physics are encoded into a set of mathematical relations between what can be called input data and output results. For every input the output is determined by the form of these relations (for instance, by some differential equations) which in turn are fixed by some general principles, but not only. These relations frequently (not always!) contain some “magic” numbers which Hawking calls “fundamental” which are not determined by general considerations.

The problematics of AP is properly be formulated as a conflict between *general principles* according to which natural laws are organized, and the *life functions* these laws must facilitate. I will try to show that resolution of this conflict cannot be achieved by tuning which does not exclude trial and error, but requires *intelligence*. As I will argue below, the constants cannot be tuned because there are too few of them to satisfy all the requirements of life[2]. How few? A definite answer is possible for a particular part of physics which is relatively well understood, namely, on the area which includes physical chemistry, physics of condensed matter and has a direct relevance to biophysics. Although the so-called "Theory of Everything" has not yet built, but the "Theory of Everything Chemists Need," (TECN) does exist. For people familiar with physics, I would say that TECN is a theory which describes matter on low (subnuclear) energies and intermediate spatial scales (larger than the size of nuclei, but smaller than the planetary ones). So it takes existence of stable atomic nuclei for granted and does not discuss effects of gravity. It greatly helps the discussion that this theory can be formulated in a closed mathematical form; it includes the Schrödinger equation with the potential term depending on the position of nuclei and electrons interacting via the Coulomb's law and the spin-orbit interaction. As is shown in Appendix A the main equations of this theory are so short that occupy just half a page. The mathematical formulation of this theory is not just terse, it is also very constrained. In addition to the values of the charges of the nuclei given by integers, there are only three "free" (i.e., not defined by the theory itself) parameters: the so-called fine-structure constant "alpha", which characterizes the strength of the electromagnetic interaction, the ratio of the mass of the neutron to proton mass (approximately equal to 1) and the ratio of the mass of the proton to electron mass (approximately 1840). It is striking that the theory with such a small number of free parameters can describe an incredible diversity of the processes occurring in the matter! Even more strikingly, the solutions of these equations describe the enormous amount of stable molecules of almost any degree of complexity involved in biochemical processes.

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[2] This argument has been made before. For example, in John Leslie's book *Universes* (on fine-tuning and multiple universes, published in 1996, he states:

"One of the problems with this [multiverse] scenario is that it appear unable to account for the above mentioned remarkable fact, very regularly overlooked, that one and the same constant often seems fine-tuned in ways satisfying several different needs at once." (pp. 101-102) Leslie then goes on to say that it looks like the multiverse would have to have varying laws in order to get a law such that the constants satisfied all the needs at once.

Dimensionless constants. In order to understand better this important concept I will consider an example of the simplest of all atoms –the hydrogen atom. Suppose we have a hot hydrogen gas; as every hot substance it glows emitting light. If we put the light beam emitted by the gas through a prism it will be split into a variety of colors (this is called spectral analysis). Each color is associated with an electromagnetic wave of a certain frequency, that is to the number of times the electromagnetic wave oscillates every second. It turns out that all frequencies emitted by hydrogen atoms can be represented by the formula (the Rydberg series):

$$\nu_{n,m} = \frac{1}{h}\left(E_n - E_m\right),$$

$$E_n = mc^2\left[1 - \frac{\alpha^2}{2n^2} + A(n)\alpha^4 + \ldots\right]$$

where there mc^2 is Einstein's famous expression for the energy of the electron (this is the maximum energy that can be extracted from it, by completely destroying the electron), **h** is the so-called Planck's constant, alpha **α = 1/137** is the fine structure constant, ***n, m*** – integers, A (n) is also a certain number whose value is immaterial to us, and the points represent the higher members of the series in the "alpha"[2].

Now let me explain the meaning of these formulas. According to quantum mechanics, the energy of the stationary states of an electron in an atom can take only discrete values $\mathbf{E_n}$ corresponding to different values of the integer **n**. When an electron jumps from one "level" of energy to another, the atom emits light, the frequency of which is determined by the energy difference between the initial $\mathbf{E_n}$ and final $\mathbf{E_m}$ states as expressed by the formula (1). Equation (2) describes the possible values of the energy $\mathbf{E_n}$ of electron in a hydrogen atom. It is written in the form of an expansion in the small parameter "*alpha*". The first term of the expansion is simply the electron rest energy $\mathbf{mc^2}$. The next term in the expansion, written in the explicit form, contains the square of the dimensionless constant "*alpha*". All the other members of the series, symbolically marked by points, contain higher powers of this constant. Since electrons are hold in atoms by the electromagnetic force, "*alpha*" characterizes the strength of the electromagnetic interactions. As can be seen from the formulas and the numerical value of “alpha”, these interactions are relatively weak. Indeed, the difference between the energy of an electron in an atom and a free electron is proportional to the "alpha" squared ~ 1/10000.

The similar formula for the energy levels in complex atoms contains as a parameter *"alpha" multiplied by Z,* where *Z* is the atomic number in the periodic table. For atoms with large numbers *Z ~ 1 / "alpha"* the binding energy becomes comparable with the rest energy $\mathbf{mc^2}$. This limits the size of the Periodic Table, atoms with numbers greater than about 130 are simply impossible.

This very "*alpha*" represents one of these dimensionless parameters that determine the structure of matter. It is dimensionless because it is not measured in meters or seconds, it is just *a number*. In the context of "Theory of Everything Chemists Needs to Know" (TECN) the numerical value of *"alpha"* has no justification. It appears as given and is approximately 1/137. In this theory, there are two other dimensionless parameters: the ratio of the mass of the proton to the mass of the neutron $\mathbf{m_p / m_n}$ and the mass ratio of the proton to electron mass $\mathbf{m_p / m_e}$. They are also not determined by the theory itself.

General principles behind laws of nature. It is extremely important to understand that the general form of the laws in "Theory of Everything" is fixed by certain fundamental principles that science, after much effort, has managed to discover. In making new hypothesis and constructing new theories scientists do not just blindly try whatever seem to work at the given time. There are certain metaphysical assumptions they follow, consciously or unconsciously[3].

These principles include, for example, general covariance (the laws must admit a formulation independent of the reference frame of the observer), gauge invariance, the principle of linear superposition of wave functions, *etc*. The first of these principles expresses the universality and timelessness of the laws of Nature. It turns out that these general principles largely fix the mathematical form of the natural laws[4]. The greatest experimental discoveries in physics, such as the discovery of electromagnetic radiation by Hertz in 1888 and the discovery of antiparticles in the 1930-ties where predicated by the formulation of certain general principles.

What does all this have to do with life or, better yet, with us, human beings? After all, the fundamental principles discovered by science

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[3] I refer the reader to the brilliant book by Mark Steiner "The Applicability of Mathematics as Philosophical Problem".

[4] They determine, for instance, the fact that the force between two electric charges in three-dimensional space is inversely proportional to the square of the distance.

seem to be so abstract and devoid of human content. On the other hand, they determine the entire variety of complex structures, including all biochemical structures of our body, together with their functions. From these principles theorists derived mathematical equations of "Theory of Everything Chemists Need" (TECN) in their general form. Only the values of the dimensionless constants are left undetermined, at least for time being. Hence if the general principles remain unchanged (this assumption will be discussed later), then all the freedom to change the structure of the matter, making it more or less stable, amounts to a change of these constants.

Why the constants are as they are? There are various suggestions which I list below.

1. Since the laws of physics in general and fundamental numbers in particular are such to facilitate the emergence of life and eventually intelligent life able to comprehend the Universe, they reveal a purposeful design and hence point towards intelligent Creator.

2. When we will have a true Theory of Everything (ToE) that takes into account the dynamics of nuclear interactions and even gravity, we will learn that the values of the dimensionless constants are unambiguous.

Such answer implies that the universe cannot be different from what it is and *homo sapiens* comes as a part of the general package. This opens a possibility that intelligent life is just a byproduct of some general process.

3. The third answer is based on fashionable Multiverse Theory (MT) which argues that our world is only one of the almost infinite number of universes, each with its own set of fundamental constants (or may be even with different fundamental principles). Scientific status of this theory is quite shaky, but it is popular because of its ideological content. It is alleged that the dimensionless constants in the "Theory of Everything, Chemists Need", are defined locally in every universe.

MT exists in several forms. In its most extreme form it states that there are no general principles which fix the form of the laws in the entire Multiverse. In this form it radically breaks with the science tradition. It is suggested that instead of being defined by the general principles, laws of physics are fixed by Darwinian selection leading to weak AP.

There is another form of MT based on the yet unfinished string theory. The latter one admits general physical principles such as general covariance, gauge invariance and principles of quantum mechanics. In their attempts to remove contradictions between the theory of gravity and quantum field theory string theorists have arrived to the version of Theory of Everything where the number of free parameters is much greater than in TECN, an almost infinite amount. Each set of parameters is supposed to be implemented in its own universe dictating its own laws of physics. Then again comes Darwinian selection leading to weak AP.

Whatever version of MT one takes, the global picture is the same. Namely, in the vast majority of universes there are no complex structures, and hence no life, but we are fortunate to live in a one (may be the only one) in which one can live. It is frequently stated that "we would not discuss the structure of natural laws if we would not be here". The question of our existence is solved by trial and error, or rather by the Darwinian selection.

As I have said, in its extreme version the MT theory is not scientific. The quasi-scientific version of it is based on the physical theories which status is unclear. Their many aspects remain deeply controversial and the theory is challenged even by some of its founders such as Prof. P. J. Steinhardt[5]. However, we can afford to be kind and afford MT a discussion. Below I will try to show that even if some form of the Multiverse Theory will turn out to be correct, it will not be able to answer the question of why the world is not just fit for intelligent life, but is also comprehensible for intelligent beings.

The argument of self-selection is present in both the extreme ("everything is possible") and quasi-scientific forms of MT. Therefore I will deal with it first. The proponents of Weak AP frequently say that "if the laws would not be favorable to life, we would not be here to discuss them". On first glance this looks like an unbeatable argument, but, as I am going to show, it is flawed. The first flaw is that it really misrepresents the situation. To discuss laws of nature we must be aware of their existence. For most of its history mankind has not even contemplated the idea.

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[5] The readers interested in the technical details may look at the discussion on http://physics.princeton.edu/~cosmo/sciam/index.html#faq

Although the life-supporting laws may be self-selecting, the knowledge-supporting ones are not. A possibility for intelligent creatures to have knowledge of the universe imposes on the world restrictions which go much further than to be life-supporting. We can be aware about laws of nature only in the world which is not just life-friendly, but knowledge-friendly. Since MT theory does not put any restrictions on the nature of physical laws, it does not forbid the situation where the world is friendly for life just locally, perhaps even just for a single tiny planet in the vast Universe. On the other hand, to be knowledge-friendly is a very different matter. Such world must be *globally comprehensible* for creatures endowed by sufficient intellect. We could equally well live and even thrive in a world which would be utterly incomprehensible outside of boundaries of our habitat. After all there are many creatures on this Earth who are in exactly that condition and nevertheless survive wonderfully. Many of them are infinitely more ancient then people (horseshoe crabs, cockroaches, rats, just to name a few)[6].

The fact (this argument was put forward by my colleague physicist Alexey Burov) that we do not need just to explain our existence in the cosmos, we have to explain the fact that we are capable to comprehend it. "**Man** shall **not live by bread alone**, but by every word of God." (Luke 4:4)

And the limits of our understanding are immeasurably wider than the limits of our environment. We are not just observers, as they call us in the theory of many universes, but *cosmic observers* or "comprehencers". And it is here that the real mystery is and the theory of many universes can say nothing about it. In this theory, our almost supernatural ability to comprehend just looks like a random fact.

What makes the world comprehensible? It is not just its inherent logical structure (laws of nature), but the compatibility of this structure with human mind. The laws of nature might be so complex that we would not be able to grasp them, that we would never even guessed that they exist. Imagine that the world has less regularity so that the number of repeatable events such as change of seasons, motion of sun

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[6] Paul Davis makes a similar points: "It is perfectly possible for there to exist a universe that permits the existence of observers who nevertheless do not, or cannot, make much sense of nature. . . .In fact, the physics of our universe is *extremely special*, being both simple and comprehensible to the human mind. This 'understandability factor' is left out of anthropic multiverse explanations. (Davies, Paul. 2006. "How Many Universes").

and planets, and so on would be smaller. In such more chaotic world we would not even come to the concept of the laws of nature, though our body might adapt to such conditions. It fact, the regularity of events is determined by the particular structure of the physical laws (as evidenced by the famous theorem of Kolmogorov-Arnold-Moser, to which I refer the curious reader). Hence the comprehensibility of nature is conditional on the special structure of its laws.

Quote "the formula of impossibility" by Alexey Burov:

> "According to the logic of the cosmological Darwinism, the proportion of cosmically -observed [i. e. comprehensible - A. Tsv.] worlds among all habitable worlds is zero. The condition of cosmic observability of the universe is a very strong demand, additional to local observability, and, as such, strongly restricts the class of habitable universes. Impossible in this logic is not some kind of consciousness, but the one which is capable to observe and comprehend the universe as a whole, to be a cosmic observer."

The extreme "everything is possible" MT has only one justification for it, namely, the self-selection argument, and, as was demonstrated above it tries to achieve its purpose by the slate of hand, substituting one argument for another. So, there is no reason to discuss it further. One may argue that the quasi-scientific version of MT theory would perform better, but the self-selecting argument fails there for the same reason.

Let us return therefore to our table of APs and consider the statement number 2 where intelligent life is thought as just a byproduct of some general structure of things. Is such situation plausible? I will argue that it is not. The reason for this is there appear to be a conflict between general abstract principles laid at the foundations of physics and *requirements of functionality* imposed by the very essence of life. These requirements emerge in multiple forms and can be mathematically formulated as restrictions on the dimensionless constants of physics. While looking at pages of "The Anthropic Cosmological Principle", one is struck by the fact that the same dimensionless constants appear in parts of the book that discuss completely different problems. There are pages on which conditions for the star formation are discussed, and there are those which discuss the question why the age of the universe must be several times greater than the time of biological evolution. Here it is written about the number of elements in the periodic table (it is ~ 1 / "alpha"), and here one reads about properties of water. All these topics are discussed because they are important for *performing certain functions* vital for the existence of life. A successful performance of each function imposes a certain condition for the dimensionless parameters. The conditions are many, but the number of the dimensionless parameters is few. In TECN, which restricts the consideration to the problem of stability of chemical structures there are just three of them. If we add gravity and nuclear physics, there will be still less than ten parameters. According to the quasi-scientific version of Multiverse Theory, these parameters are not fundamental, i.e. they depend on the infinite number of other parameters. If the Multiverse Theory is correct and the fundamental parameters are chosen randomly than the ones of TECN are just random numbers. This amounts to saying that the problem of finding a world suitable for intelligent life is solved by trial and error.

Let us stop here for a moment and think about it. The Multiverse Theory tells us that the mathematical problem of finding solutions for the life-supporting conditions was solved by trial and error**. However, not all mathematical problems can be solved by trial and error and this includes the problem we are interested in**. The point is that while the stability of the material structures in our Universe is determined by only three dimensionless parameters, the number of conditions to which they must satisfy is greater than 3 by far! In fact, it is almost countless. Problems of that kind are not solved by trial and error, because, as a rule, they have no solutions, unless the structure of the system is specifically designed for a solution to exist!

This point is extremely important and I would ask the reader to be a little patient, risking to torture him by dull arguments. In my defense I say that my math does not rise above the 6th grade.

I mentioned above that the conditions for the existence of life (such as we know it), impose certain restrictions on the dimensionless parameters. To get an idea of how numerous they are, let us consider examples. We know that physiological functions of our organism require existence of complicated biochemistry. This complexity is not just a fact about life as we know it, but is unavoidable requirement of any life forms since they must be able to process enormous amounts of information and to perform multiple tasks to preserve their integrity in the changing environment. This is the case even for simple life forms. We know that every living cell contains a huge biochemical laboratory. The operation of this laboratory requires numerous molecules of various complexity involved in complicated transformations[7]. Since the physics of all these processes is determined by TECN, conditions for successful performance of every chemical reaction can be expressed (at least in principle) as some equation (or rather inequality) on the free parameters of the theory. The resulting formula will contain the parameters "alpha", $\mathbf{m_e / m_p}$, $\mathbf{m_p / m_n}$ (mass ratio of the electron and proton, proton and neutron) mentioned above. Since the number of various proteins, enzymes and other molecules and molecular structures carrying biological functions is in millions, it is clear that there are millions of mathematical conditions the above parameters must fulfill, but the number of the parameters is small, only three. As I have said, this immense heap of conditions can be considered as a system of equations[8], which one must fulfill to obtain the values of the parameters necessary for existence life, our life. When the number of equations exceeds the number of unknowns mathematicians call it *overdefined system*. For such problems existence of solutions is not guaranteed. However, we know that at least one solution exists - it is given to us!

Let me consider a simple example of a problem which cannot be solved by trial and error. Let's say we're playing roulette. On the drive there are 37 digits, including 0. Each of these figures ever let fall, so the problem of obtaining the number 0 can be solved by just mindlessly spinning roulette and 0 will appear sooner or later. However, since there is no number 38 on the drive, the problem of getting 38 digits cannot be solved in principle, even tapping a billion years.

Now let us move to overdefined mathematical systems which also cannot be solved by trial and error. One simple example would be a geometrical one: two straight lines on a plane intersect at one point under generic conditions, but to achieve this for three lines requires a design. Another simple example requires some algebra. Consider a system of three equations for two unknowns, X and the Y:

$$X + Y = 2, \quad X - Y = 0, \quad 2X + Y = 0.$$

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[7] Such molecules as DNA can be as long as several hundred meters.

[8] Strictly speaking, these are not equations, but inequalities, but taking into account the immensity of their number this distinction is irrelevant.

This system has no solutions. The first two equations have the solution $X = Y = 1$, but this solution does not satisfy the third equation. Imagine now that some bad mathematician tries to solve the system by mindlessly substituting different values of the variables X and Y. It is clear that since the system has no solution the trials will not provide any result even after billions of years. We have to refer the bad mathematician to the school algebra course, which teaches that if the number of equations is larger than the number of unknowns, then as a rule, there are no solutions. However, this rule has exceptions, if the system is so cleverly designed that some of the equations represent a reformulations of others. Here's an example:

$$X + Y = 2, X - Y = 0, 2X + 2Y = 4.$$

This system has the solution: $X = Y = 1$. It is possible because the last equation is essentially the same as the first (the left and the right sides are multiplied by 2). I.e. the presence of the third equation does not bring anything new, it is a disguised equation number one!

Using more rigorous language we can say this: inside of the set of *overdefined* systems of equations there exists a infinitesimally small specially constructed subset of solvable systems.

For overdefined system to have a solution, it must somehow be specially designed or artfully constructed. In the given case this art amounts to the correct choice of the original principles at the foundation of the laws of nature, providing solutions in the presence of an overcrowded system described above.

As I have mentioned above, these fundamental principles include general covariance, gauge invariance, the principle of superposition of wave functions, *etc*. These principles are elegant and intellectually clear which suggests a conscious decision.[9] The fact that in their very abstractness the fundamental principles do not explicitly contain human beings provides them in my eyes with a special elegance. God does not impose Himself giving us a freedom to believe. I fully understand the feelings of the Artist, who saw that "it is good". This is the Anthropic Principle in its not banal formulation.

[9] I am infinitely grateful to M. Arkadiev, who clarified for me that aspect of the Anthropic Principle.

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Appendix A.

The Theory of Everything Chemists Need.

In this Appendix I will demonstrate that the fine-tuning argument is superfluous as far as chemistry in general and biochemistry in particular are concerned. The theoretical foundations of these scientific disciplines are well understood and are encoded in a system of differential equations which, as we will see, can be written on less than half a page. I will call the corresponding theory the Theory of Everything Chemists Need (TECN, for brevity). These formulae contain only three dimensionless parameters whose values are not determined by TECN itself and hence can be considered as fitting parameters. The general form of TECN can be (and was) derived from general rational principles.

TECN is not a theory of all matter, it concerns itself only with processes relevant for biology. Here to a certain approximation one can forget about gravity and nuclear energy. Gravity may be considered just as an external force acting on organisms whose strength has a given value; the nuclei can be considered as the indestructible cores of atoms which have fixed mass and electric charge.

TECN is based on a model in which matter consists of interacting atoms with indestructible nuclei. This is an approximate model which considers atomic nuclei to be indestructible and does not concern itself with such phenomena as radioactivity. All nuclei are positively charged with an electric charge being an integer multiple of the electron charge e. An element whose nuclei have electric charge $+Ze$ occupies place number Z in the Periodic Table of the Elements. Nuclei consist of electrically charged protons and electrically neutral neutrons. The number of neutrons in nuclei of a given element can vary; nuclei with different numbers of neutrons are called isotopes. For example, we know three isotopes of hydrogen: ordinary hydrogen ^{1}H, whose nuclei consist of just one proton and no neutrons, deuterium ^{2}De, which nuclei consist of one proton and one neutron, and tritium ^3T, whose nuclei consist of one proton and two neutrons. Usually only one isotope is stable and all other isotopes decay with various half-lives and hence are less abundant.

Isolated nuclei form atoms or molecules where positively charged nuclei bind an appropriate number of electrons (usually this number is equal to the atomic number *Z* of the given nucleus, so that the atom is electrically neutral). In condensed matter such as liquids or solids electrons cannot be considered to be bound exclusively to given nuclei. It is energetically advantageous for them to be shared between different nuclei and this serves as one of the mechanisms of chemical bonding.

After this brief introduction I will proceed with the mathematical formulation of TECN. I believe that this formulation may be beneficial even for those unfamiliar with mathematics since it demonstrates a very simple point, namely, the utter simplicity of this fundamental theory. As the reader can see, the equations occupy is less than a page.

The fundamental equation describing the dynamics of a system of *N* nuclei with atomic numbers of Z_1 , Z_2 , … Z_N and masses M_1 ,M_2 ,… M_N and N_e electrons is described by the Schrödinger equation:

$$i\hbar\frac{\partial}{\partial t}\Psi\left(t;\vec{R}_1,...\vec{R}_{N_{nucl}};\vec{r}_1\sigma_1,...\vec{r}_{N_e}\sigma_{N_e}\right)=\hat{H}\Psi\left(t;\vec{R}_1,...\vec{R}_{N_{nucl}};\vec{r}_1\sigma_1,...\vec{r}_{N_e}\sigma_{N_e}\right),$$

Eq. 1,

where Ψ is the wave function knowledge of which enables one to calculate all observable quantities related to the given system. The wave function contains as its arguments time *t*, the spatial coordinates of the nuclei ***R*** and the spatial coordinates of the electrons ***r*** together with their spins $\sigma = +\_1/2$. Spin is an internal degree of freedom of an electron related to its angular and magnetic moment. In other words, an electron resembles a spinning top and the projection of its angular momentum on a given coordinate axis is quantized and is equal to the product of the Plank's constant and $\sigma = +\_1/2$. The wave function changes sign under permutation of any pair ($\mathbf{r}_i$,σ_i),(r_j ,σ_j) (the Pauli principle). Since the nuclei are usually immobile, one does not need to take into account their spins.

The operator *H* acting on the wave function on the right hand side of the equation is called the Hamiltonian. Its form specifies the theory. The remarkable fact is that in the case of TECN the Hamiltonian can be written explicitly (all formulae below are written in SGS units):

$$H = -\sum_{j=1}^{N_p} \frac{\hbar^2}{2M_j} \frac{\partial^2}{\partial \vec{R}_j^2} - \sum_{k=1}^{N_e} \frac{\hbar^2}{2m_e} \frac{\partial^2}{\partial \vec{r}_k^{\,2}} + U_{Coulomb}(\{R\},\{r\}) + H_{spin-orbit},$$

$$U_{Coulomb}(\{R\},\{r\}) = \sum_{j<p}^{N_p} \frac{Z_j Z_p e^2}{|\vec{R}_j - \vec{R}_p|} + \sum_{j<p}^{N_e} \frac{e^2}{|\vec{r}_j - \vec{r}_p|} - \sum_{j=1}^{N_p}\sum_{k=1}^{N_e} \frac{Z_j e^2}{|\vec{R}_j - \vec{r}_k|},$$

$$H_{spin-orbit} = -i\frac{\hbar^2}{m_e^{\,2} c^2} \sum_{j=1}^{N_e} \left(\frac{\vec{\partial}}{\partial \vec{r}_j} U_{Coulomb}\right) \bullet \left(\vec{S}_j \times \frac{\vec{\partial}}{\partial \vec{r}_j}\right).$$

Eq. 2

It consists of the kinetic energy of the nuclei and the electrons (the first two terms in the first line), the electrostatic potential energy $U_{Coulomb}$ and the spin-orbit energy $H_{spin-orbit}$ which reflects the action of the electrostatic field of the nuclei on the spins of the electrons. The last term constitutes a relativistic correction to the Hamiltonian. This form of TECN is applicable only to systems of those elements which nuclei are not too heavy. On the other hand, such heavy elements as radium, uranium and beyond are radioactive and irrelevant for biology.

It is already quite remarkable that complete information about all chemical processes can be packed into a single differential equation. More remarkable still is the fact that this equation contains only three dimensionless parameters. To see this we have to perform some simple operations. Specifically, I will rewrite the above formulae in dimensionless units, by introducing the following notations:

$$r = \frac{\hbar^2}{e^2 m_e} x,$$

$$E = \frac{e^4 m_e}{\hbar^2} \varepsilon$$

Eq. 3

Now distances are expressed not in centimeters, as in Eqs.(1,2), but in the unit of characteristic atomic size; energies *E* (recall that Hamiltonian has a dimension of energy) are expressed not in ergs, but in unit of the ionization energy of the hydrogen atom. Now *x* and ε are just numbers. Rewritten in these units the Hamiltonian of TECN becomes Eq. 4:

$$h = -\sum_{j=1}^{N_p} \frac{m_e}{2M_j} \frac{\vec{\partial}^2}{\partial \vec{X}_j^2} - \sum_{k=1}^{N_e} \frac{1}{2} \frac{\vec{\partial}^2}{\partial \vec{x}_k^2} + u_{Coulomb}(\{X\},\{x\}) + \alpha^2 h_{spin-orbit},$$

$$u_{Coulomb}(\{X\},\{x\}) = \sum_{j<p}^{N_p} \frac{Z_j Z_p}{|\vec{X}_j - \vec{X}_p|} + \sum_{j<p}^{N_e} \frac{1}{|\vec{x}_j - \vec{x}_p|} - \sum_{j=1}^{N_p} \sum_{k=1}^{N_e} \frac{Z_j}{|\vec{X}_j - \vec{x}_k|},$$

$$h_{spin-orbit} = -i \sum_{j=1}^{N_e} \left(\frac{\vec{\partial}}{\partial \vec{x}_j} u_{Coulomb}\right) \bullet \left(\vec{S}_j \times \frac{\vec{\partial}}{\partial \vec{x}_j}\right)$$

Eq. 4.

This formula contains three dimensionless parameters:

$$\alpha = \frac{e^2}{\hbar c}, \qquad \beta = \frac{M_p}{m_e}, \qquad \gamma = \frac{M_n}{M_p}$$

Eq.5.

-the so-called fine structure constant α, the ratio of the mass of proton to the mass of electron β,and the ratio of the mass of neutron to the mass of proton γ. The latter two constants are encoded in the ratios of the electron mass to the masses of the nuclei: $M_j/m_e = \beta (Z + N_n \gamma)$.

The approximate numerical values of these constants happen to be $\alpha = 1/137$, $\beta = 1840$, $\gamma = 1.0013$. If somebody played dice with our Universe subjecting it to some Darwinian process, as the authors of the multiverse theory suggest, it is these three parameters which could be varied. All other parameters in Eq.4, such as the number of nuclei of a given kind, their charges *Z*, their number of neutrons, the total number of electrons in the system, are just integer numbers.

In practice the choice of these numbers α,β,γ is also very limited. The elements playing the most actively role in biochemistry are Hydrogen (*Z*=1), Carbon (*Z*=6), Nitrogen (*Z*=7), Oxygen (*Z*=8), Sodium (*Z*=11), Phosphorus (*Z*=15), Chlorine (*Z*=17), Potassium (*Z*= 19), Calcium (*Z*=20), Iron (*Z*= 26). A tiny bacterium needs seventeen elements, and humans need twenty seven, including such exotic ones as molibdenum. As I have said, Eqs. (1,4) contain all information about chemistry and even, in principle, all information about the functioning of living cells (although in practice it might be difficult to find and interpret the solutions that would encapsulate this information). From this rather meager set of ten elements subject to the Schrödinger equation springs a plethora of biologically active molecules with innumerable functions. In order to be functional these molecules must have quite particular properties and there are too many of them to solve the problem by fine tuning just three parameters. Of course, the parameters must have the right values, but this is not sufficient. The problem was solved not by throwing a dice, but by an extremely clever choice of the basic principles of physics which determined the form of TECN. This was a really Intelligent Design.

Appendix B

Order and Chaos. The early Universe as exceedingly special state.

As has been mentioned in the main text, despite of a lack of any definite forms in the early Universe it would be wrong to characterize its state as chaotic. To appreciate this fact we need to delve into the notions of chaos and entropy as the measure of it as they are understood in physics.

The notion of entropy is well defined only for macroscopically large systems and the Universe is certainly one. In the statistical approach to such systems one is not interested in such details as behavior of every constituent particle. Instead we look only at quantities averaged over macroscopic regions which magnitude scales with the number of particles or with the volume of the region. Such approach can be illustrated by an example of an air in a closed volume. At atmospheric pressure the number of molecules in one cubic centimeter is exceedingly large ~ 10^{23}. As I have said, we do not follow movements of every molecule as these details do not affect such *extensive* quantities as pressure and total energy of the gas. The same pressure or total energy is realized for many different configurations of molecules. For instance, they will not be affected if we interchange their positions. The notion of entropy refers to the number of ways one can change microscopic details of the system without changing the values of its extensive (that is macroscopic) properties. More precisely, the entropy is defined as a logarithm of this number. Let us consider a simple example. Imagine we have a collection of N cells with a weight of certain mass positioned in each cell. Let our macroscopic state be characterized by the total mass of the system. This mass does not change if we permute the weights and there are $N! = 1x2x3x4x\ldots xN$ such permutations. So the entropy of such macroscopic state is $S = ln\ N!$ At large N the factorial can be well approximated as $N! = e^{N\ ln\ N}$ (e = 2.721828…) so that $S = N\ ln\ N$. It is proportional to the total number of particles in the system and therefore it is indeed an extensive quantity.

According to Second Law of Thermodynamics entropy of a closed system always grow with time. So in the beginning our Universe had smaller entropy than now. So the number of ways to realize its initial state was much smaller than the corresponding number now. In that sense we say that it was more special in the beginning than it is now. To estimate the degree of this specialization, we should look at the maximal entropy which will be achieved when all matter in the observable Universe will collapse into black holes. Black hole is a perfectly featureless object, a perfect equalizer, the symbol of death itself. Hence it absorbs everything and nothing comes of out of it, its entropy per a unit of mass is maximally possible. The corresponding estimate was done (see, for example the book by Roger Penrose) and it gives for the maximal entropy of the Universe a stupendous number 10^{123} meaning that the initial choice was approximately 3 to 10^{123} power. This is how special our Universe is (and may be even more). It is special, but in what way? Roger Penrose who made this argument in his books explains that the sign of low entropy was the extreme homogeneity of the Big Bang.

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