

Consciousness Bootstrapped

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Abstract: Starting from just the logical possibility of self-aware experience as an information process, consciousness can be bootstrapped into existence with a minimum number of random events capable of happening by chance in a landscape of cosmologies. This essay follows the passage of emergence through logic, mathematics, physics, chemistry, biology and psychology as a high level overview bringing together the authors ideas previously explored in earlier FQXi essays.

Introduction

Our universe is vast. A septillion stars burn within the observable horizon alone, bathing their planets in varying amounts of heat and light. They burn out, explode, form planets and new stars, eventually exhausting their fuel, fading into dead remnants, they are doomed to sink into a super-massive black hole waiting at the centre of each galaxy.

The process is beautiful in its complexity but without goals. The cosmos simply follows the laws of physics in random motion, increasing entropy until it reaches its final state. Except, **with great rarity** where a planet and its star exist with just the right conditions, **life forms spontaneously and evolves**. Eventually, if luck holds out for billions of years, it can reach an advanced state of self-awareness. The rule that entropy must always increase is respected, but in exchange for disorder elsewhere, life itself can decrease its own entropy, organising its environment, gaining purpose, at least for a short while.

How and why did this come to be? There are many who look to religion for answers to these questions, but in the past the actions of Gods were needed to explain many things that are now understood through science. Birth and death are biological processes well understood within the laws of physics. The vagaries of the weather and natural disasters were once attributed to the wrath of deities, but are now known to happen through the forces of nature regardless of whether our own behaviour is good or evil. Even our own emotions are reduced to processes of neuroscience within a brain following a path determined by the laws of physics.

Yet three important gaps remain in our understanding of how it all happened. How was the universe created? How did the genesis of life come about? What is consciousness? Even if science can plug these gaps it leaves open the biggest question of all: **Why is there something and why is it as it is?** Who enacted the so-called laws of physics that made it all possible? Some will still believe that only the Gods can account for this, but the existence of Gods raises more questions than it answers. I am not saying that religions are wrong or that those questions do not have answers. What I will do in this essay is suggest an alternative.

What follows is my sketch of how and why we came to arrive in this world, wanderers with our own goals, emerging naturally from pure logic alone.

Logical Possibilities

Our individual experience of life is one of many logical possibilities. Different people have a different experience, but it is also possible to imagine very different experiences that could come from a universe where different physical laws hold. Indeed we can use computers to simulate different possible universes and record the experience of some observer within that simulation. This does not mean we are in some kind of simulation. It is just a source of examples to show how varied different life experiences could logically be.

A possible experience then, is a flow of information from some possible universe. If the information is a random stream of symbols then it is unintelligible and no useful understanding of the logical environment can be gained, but the information that our brains gather from our journey through our universe is not random. With our combined intelligence we can form remarkable understanding of how our universe functions.

You may ask “Do these alternative logical possibilities exist in the same sense that our experience exists?” **Existence is a relative concept.** The word “existing” is used to describe anything from our universe that we can experience with our senses directly or indirectly. The word may be used for transcendental concepts as well as physical objects. In an alternative logical possibility for an experience of some different universe, an observer might use a similar word to describe anything it can experience. So for us anything in our universe exists, and for them anything in their universe exists. There is nothing special that makes our concept of existence different from theirs. **No magic spell is required to bring our world into existence.**

The ensemble of logical possibilities for an experience is something we can explore through the use of mathematics. Indeed, a possible experience could be defined as a subset of the information that describes a mathematical structure.

The standard next step is to declare this collection of mathematical structures to be the top level multiverse of possible universes. It could be assumed that our universe is chosen from these by a random process where each structure has a probability weighting favouring simpler universes. This would work in combination with the anthropic constraint that our universe must have intelligent life within it. That is not quite how it works. Such a weighting would be problematical. What objective quantification of simplicity would favour the laws of physics we know, and how is that decided? These questions have unique answers, but an atheistic universe must be constructed in some unique way that does not require arbitrary judgement.

In fact the collection of possible mathematical structures is not simply a set of discrete objects. There are relationships between them. Some structures may be equivalent in the sense that they provide the same observer experiences. There may also be relationships between parts of the structures. The ensemble is therefore described by a category rather than a set. If further levels of abstraction are used a higher dimensional algebraic structure will be needed. This is something more complex. It is my view that the laws of physics are derived from a universal collective behaviour that emerges from this structure [1].

In this view of reality physics is described by a unique algebraic master theory that emerges from universality in the mathematical system of logically possible experiences. In this theory, space and time are not apparent. **Geometry must emerge naturally at a subsequent step.**

Algebraic structures such as Fields can be understood in terms of their symmetries via Galois Theory. This is the underlying reason why group theory is so important in physics. Different groups or symmetries can be arranged in a hierarchy by the relationship of homomorphism. At the top of the hierarchy is the free group on an infinite set of generators. All other groups can be derived from the free group modulo a set of imposed relations. It is not widely known that the free Lie group has some remarkable structure that can be related to physics via the free Lie algebra. In its simplest form this structure can be defined in terms of tensor products for tensors of arbitrary rank. The structure can be envisioned as discrete open-ended strings of vector spaces. **By a surprising reduction the algebra can also be represented by closed necklace algebras where the open strings become discrete closed loops.**

The next step is even more extraordinary. It turns out that there is a Hopf algebra homomorphism defined in terms of iterated integrals from this structure to the algebra of functions on continuous open or closed string embedded in a manifold [2]. In other words, **it is possible to step very quickly from a simple idea about how the algebraic master theory should be, to something that looks like the kinematic basis of string theory.**

The full analysis of how this works will be much more complex. The master theory will need to embrace multiple levels of abstraction so that it is described in terms of a higher n -category theory. The nature of symmetry will likewise be enlarged via the generalised Galois Theory of Grothendieck, embracing n -groupoids, supersymmetry and deformed q -groups. If all that can be accomplished **there is hope that the resulting master theory can be mapped to geometry to reconstruct a full non-perturbative formulation of superstring theory.** Needless to say this picture of how physics might emerge from pure mathematical logic is highly speculative and a full understanding of whether this is possible may be decades away from achievement. **The take-home point is that there is already an outline path which leads from an analysis of logical possibilities to the laws of physics.**

The Origins of Cosmology

When people contemplate the origin of our universe they intuitively look back to the big bang event and ask “what caused that to happen, was there something before?” This is the wrong question to ask. The universe must be read as a whole. **Temporal causality is merely emergent** [3] and the big bang is just one particularly extraordinary event in space and time that may or may not have been the earliest in cosmology.

According to quantum mechanics, the universe is described by a sum over all possible space-time histories. Where one moment in a possible history matches others in the vast realm of possibilities, they interfere and merge. Our conscious experience is an information path through this ensemble.

The meta-laws of our reality over which the sum ranges are the master equations of string theory that are prior to the emergence of space and time [4]. String theory is known to have a landscape of vacuum solutions numbering 10 to the power of 10 to the power of some small number. In other words a few thousand bits of arbitrary information define the laws of physics as we know them, but there is only one sum (or integral) over all logical possibilities and all these solutions can be found within it at superselection points. **Importantly, the sum must be complete.** You can't limit it to just the solutions we are familiar with in our limited experience. Everything contributes to the whole. Whether you call it a multiverse or a universe is just semantics and of no consequence.

Space and time with varying numbers of dimensions emerge at many points in this sum. The exceptional mathematics of the octonions plays a special role in forming the 11 dimensional solution of M-theory. Lower dimensional points are more numerous, but many are sterile. The vacuum energy is typically large, leading to a tightly curved de-Sitter or anti-de-Sitter geometry in which little of interest can happen. In a tiny fraction of configurations the energy of the fermionic and bosonic modes (which have opposite sign) nearly cancel for the lowest energy vacuum, leading to a nearly flat universe like our own cosmology.

Gravity is crucial in shaping the universe, not just the geometry of space-time, but also the emergence of causality. The thermodynamics of the gravitational force is characteristically different from that of the vector boson forces in that gravitational objects have a negative heat capacity. In a system governed by electromagnetic forces the highest entropy state is a smooth bath of thermal black-body radiation, but as a star radiates heat its gravity causes collapse. Ultimately this can produce the highest entropy state of gravity, a black or white hole. At its centre the temperature and density of matter rises until a singularity is formed. Now forget the temporal language. The sum over histories does not know about temporal causality but within its sum these singularities emerge just the same.

Physics is holographic. The quantity of information in a region of space is limited by the area of the surface surrounding it rather than the bulk volume. **This implies that the laws of physics hide a complete symmetry**, where there is one degree of symmetry for each degree of freedom [5]. The symmetry implies a redundancy over the degrees of freedom in the bulk volume so that only the infinite hierarchy of conserved charges measurable on the surface carry real information. Where singularities form, this complete symmetry of the master theory is revealed in its full glory and the information content must reduce to near zero. **This means that entropy around a space-time singularity is low, setting a localised constraint opposing the natural tendency for entropy to maximise elsewhere.** In this way a thermodynamic arrow of time emerges. Where the spatial extent of the singularity is sufficiently large and isolated from the thermodynamic influence of other greater singularities there is an opportunity for complex non-equilibrium physics to manifest. **This is the case for the region we know as the observable universe.**

The Formation of Worlds

A low entropy big bang creates an environment in which complexity can emerge and evolve. Sufficient space and opportunity is necessary but not sufficient. A cosmology within the string theory universe will have gravity, particles and forces, but **whether anything interesting can develop there also depends on the spectrum of particles and the strengths of the forces that differ from one vacuum state to another.** So what happens in our cosmology?

As the initial soup of particles cools, a slight imbalance of matter over anti-matter develops due to tiny asymmetries in CP. Next, the Higgs field breaks the conformal symmetry giving particles a small mass. **Without these features our cosmology would be just a bath of radiation.** As the universe cools further protons and neutrons are formed, which then fuse to create helium. If the balance between the strong nuclear force and the electromagnetic force were not just right, atoms heavier than hydrogen would not be possible. Gravity and dark matter are the next players, bringing the gases together in the centre of huge stars which burn for a few million years. At their hearts the conditions of temperature and pressure become right to fuse triplets of helium nuclei to form carbon. **This is only possible due to a specific resonance that seems to have just the right energy by chance.** The

process of fusion can then continue to higher atomic numbers forming oxygen, silicon, sulphur and finally iron, the heaviest nucleus that can form through exothermic fusion.

As the nuclear fuel in the early stars runs out, the weak nuclear force comes into play causing the star to explode in a bright supernova with a burst of neutrinos **freeing the elements from their gravitational prison out into space**. In time, the dust from the first stars settles back together forming new smaller stars that burn for longer. This gives time for other heavier elements to form by neutron capture.

Astrophysics fuelled by nuclear reactions is violent. The delicate processes of life would not survive were it not for the formation of planets. If they are the right size and at the right distance from the right kind of star, their protective atmospheres and magnetic fields shield them from the harmful radiation of space. **On the protected surface of these planets nuclear reactions are replaced by the richer and much calmer processes of chemistry.**

In my estimation, the circumstances that make all this possible are incredibly unusual in the realm of possible universes. Many of the situations that make the forging and distribution of chemical elements possible are happenstance. It is not simply a case of the laws of physics being sufficiently complex. **Our universe is fine-tuned to make complex processes possible.**

There are really only two ways I know that can explain this. Either there is one universe designed by a higher intelligence to be suitable for life, or there is a sufficiently large landscape of cosmologies with a diversity of physical properties that some subset of them meets all the necessary conditions by the laws of chance. It is this second possibility that I am trying to justify. Research in string theory does indicate that such a landscape is present.

The Genesis of Life

Biogenesis - the process that initiated life on Earth – remains a mystery. Yet enough is known about biochemistry to see that it was a natural process. **No miracle was required.** All life as we know it is based on molecules of DNA which are copied with the aid of RNA, controlling and responding to the environment through the production of proteins. These life processes are supported by the properties of a range of other chemicals – water, sugars, lipids, salts, etc.

Prior to DNA there is evidence that an RNA-only world was sustained. The evolutionary steps before and in between are not known, but there is no reason to doubt that they were driven by pure electrochemical processes. The main elements with the right chemical properties to form the necessary organic molecules are **Carbon, Hydrogen, Oxygen and Nitrogen with Phosphorus and Sulphur** also playing important roles in the chemistry of the nucleic acids and proteins. As we have seen, these also happen to be the elements with the right nuclear properties for stellar synthesis making them abundant on rocky planets. **Is this coincidence, fine-tuning, or just a case of life taking the opportunity to use the chemicals that were available?**

A more tractable question that provides a partial answer is this: **Are there alternative possible forms of biochemistry regardless of elemental abundance?** Organic chemistry requires macromolecules to codify information and engineer the chemical processes that take place in a living cell. Life is based on carbon because it can form chains and bond to other elements. It has been speculated that silicone – another abundant element – could work as an alternative to carbon. It's an appealing idea, but the reality is that silicon does not have the versatility of carbon for forming stable chain molecules. In

particular, it does not easily form the double bonds that are common in organic chemistry. Silicon's role in life is limited to the silicates that form the rocky substrate of planets on which life exists. This suggests that biochemistry is not simply opportunistic. **The chemical basis for life that we find on Earth is probably unique, suggesting that the chemical and nuclear properties of the abundant elements are fine-tuned to that purpose.**

Evolution of Intelligence

A principle characteristic of life is that it organises itself and its environment in order to promote the survival of itself and its progeny. Life as we know it has developed this capability through the natural processes of reproduction and evolution. Higher organisms such as ourselves have developed positive and negative emotions as one way of aiding survival but these also result in us setting ourselves goals that give us pleasure without affecting survival. **These include the curiosity driven will to understand nature.**

By organising, life reverses the effects of the second law of thermodynamics, causing a local decrease in entropy. To ensure the second law is observed, entropy elsewhere must go up by a greater amount. For example the almost unidirectional rays of light from the Sun are put to work and heat is reradiated in all directions through dissipation.

Life organises by taking in information from its environment and processing it to find a response that achieves its goals. In higher lifeforms this information processing takes place at two levels. Cells carry an information program encoded in DNA that makes proteins in response to chemical and electrical signals. At a higher level the central nervous system processes information from our senses using cognitive reasoning to determine a response. More primitive lifeforms have only the former capability, but it is still enough to give them a semblance of purpose.

The process of evolution has brought us to our current condition through many remarkable steps. Cells formed 4 billion years ago, photosynthesis began 3 billion years ago, Eukaryotes at 2 billion years, sexual reproduction and multi-cellular life about one billion years ago. After that the rise of ever more sophisticated lifeforms evolved more rapidly.

This was made possible by the existence of a stable planetary environment that has lasted billions of years, plus a rich repertoire of chemical and electrical properties in the periodic table. **While the properties of the more abundant elements seems fine-tuned to DNA-based life, subsequent uses of chemical properties for the development of higher organisms is more opportunistic.** Nevertheless, the serendipity is impressive with almost every one of the reactive elements in the first four periods up to bromide playing some critical role in biological function, boron in plants, fluorine in teeth, calcium for bones, iron for blood, chlorine for photosynthesis, selenium in nerve cells etc.

Apart from the starting point of DNA, evolution could have taken many different turns leading to a lower final state of lifeforms. As it was, the occasional global disaster was required to bring about mass extinctions on Earth to kick evolution into a new and better direction. **Truly Earth-like planets with the right level of stability and instability will be rare but sufficiently plentiful in any given galaxy.** I think the sequence of chance events that led to intelligent life on Earth is much less common.

As self-aware beings in the universal landscape of logical possibilities, **we are rare, but not random.** We came to be here through the natural processes of anthropic selection and evolution. Our place in

the landscape of vacuum solutions of the master theory may be determined by a few thousand bits of information at most. This is a finite resource that must be used sparingly to select the low energy laws of physics conducive to life.

No doubt many of the cosmologies that exist within this landscape can harbour life, even if only through unlikely random chance events, but **we are more likely to find ourselves in a world where the probability of intelligent life is higher**. That is, one where the laws of physics and chemistry are fine-tuned to give evolution a fair chance. **It may take 400 bits from the few thousand that specify our local vacuum state, just to ensure that dark energy is sufficiently small to make the universe large**. It must be large enough so that one of the rare Earth-like planets follows a sequence of evolutionary events that ends with intelligent life before some cosmic disaster destroys it. If there are other ways to make the universe large without expending 400 bits on fine-tuning the cosmological constant then you can be sure that the universe found one, even if our theorists can't. **The remaining precious bits are used to fine-tune many other parameters needed to make the universe as hospitable to life as possible**.

Effectively, intelligence has bootstrapped itself into existence within the vast system of logical possibilities in a series of computational steps. The first step is programmed with just the **few thousand bits** available to specify a geometric physics within the universality driven master theory. **Only the anthropic principle is available** to select the most effective set of bits for producing a universe that allows the more efficient process of evolution. Our genetic DNA **perfected by natural selection** uses **over a billion bits** to program our life functions. Our brain then takes information processing to a whole new level with a memory capacity estimated in **quadrillions of bits**. Evolution has given us the **capacity to learn** an incredibly complex web of useful facts in order to survive well. Beyond that we use the collective research of many generations of intelligent men and women to place a body of knowledge at our disposal far greater than any individual can assimilate. **Our universe has found a way to bring us to this state of informational organisation with a near optimal minimum number of random choices**. We may not quite be the best possible but we should expect to at least be typical of the top rank.

The Emergence of Consciousness

What then is this thing we call consciousness? The sensation of self-awareness that we experience seems to go beyond what can be explained by the laws of physics, but does it? There are plenty of people including scientists who believe that consciousness can only be explained by something additional to the mechanics rules of our universe. They suggest **a life force that brings about consciousness**. Something is there that makes the qualia of our experience real. This point of view has a quasi-religious character. It raises more questions than it answers, yet it is impossible to dismiss directly. Instead an alternative must be found.

At the other end of the spectrum there are philosophers who deny that there is a “hard problem” of consciousness at all. Consciousness is just psychology they say. **If we can show that the thoughts of the human mind can be reduced to electrical and chemical impulses like any other biological process, what more needs to be said?** If we view consciousness from outside there is nothing more to explain. People asking questions about the nature of their conscious experience are merely confused by the self-referential nature of thought that induces a peculiar sense of self-awareness. **If they think there is something more, then they are falling for an illusion**.

Imagine that at some point in the near future it becomes possible to create a computer based simulation of your brain at the level of individual neurons. The simulation has all your memories and replicates your thoughts and emotions perfectly, but it is potentially immortal. It can either be placed in a robotic version of yourself or within a larger simulation that can provide a heaven-like experience for as long as you want. The catch is that your own brain must be destroyed in order to make the copy and it can only be done while you are young and in good health. Your reaction to this hypothetical opportunity might be stated as one of the following:

- This will never be possible because an electronic computer does not have the technical ability to replicate the function of qualia – I need to keep working on getting to real heaven.
- This is possible but the simulation would not be conscious.
- The simulation would be conscious but it would not be my consciousness – It's more like an immortal clone than an immortal me.
- It would only be conscious if it remained connected by senses to our universe – It's a way to achieve immortality but not heaven.
- This can take me to heaven – sign me up!

How can you determine which of these is right? **The first option is falsifiable**, but the others cannot be distinguished by any scientific experiment, other than by trying it yourself. Perhaps the distinction is therefore meaningless, but what does that say about consciousness, and should you take up the chance?

What can the simulation argument tell us about consciousness? In my opinion it will soon be technologically possible to run very convincing simulations of reality on powerful computers. As in a computer game, this simulation does not need to be perfect to fool its players. If a virtual someone looks down a microscope or tries a physics experiment, more detail can be patched in to make the result look convincing. We can explore the simulated world ourselves with virtual reality. In the future it may be possible to populate the simulation with artificially intelligent beings, or even simulated copies of ourselves. **Such a simulation is a consistent logical possibility for our actual experience.** According to the philosophy of “existence is relative”, this world is just as real for the beings inside as our reality is for us. Are they then conscious and how do we know that we are not ourselves part of such a simulation? The simulation argument says that such mock-up realities will become more common than reality itself, **therefore it is highly probable to the point of near certainty that we are indeed inside one.**

I think the argument is flawed because it is our experience which creates our unique conscious identity, not the universe which we inhabit. If there is one simulation that creates our experience up to this time, then there are many of them. If we are in one then we are in all of them. **If the future diverges then that is no more than what quantum mechanical uncertainty predicts.** What we actually experience will be the collective behaviour of all the logically possible universes that are consistent with our experience. When we experiment with particles we are observing the emergent properties of information being processed in the quantum ensemble of possible worlds. Space, time, world-lines, strings and membranes are just manifestations of the possible relationships and partial morphisms that describe the similarity connections between them. **An experience in a world that does not follow the universal rules of the master theory, or one where we did not arrive by the natural processes of evolution, is simply too improbable to be real.**

Does this imply that a simulated mind is not conscious? No, our brain is just a wet computer whose workings can be replicated electronically. **If an artificial intelligence is able to interact with the**

universe and be aware of itself then it is certainly conscious. Can our conscious minds be transferred or copied to computers, or continue to exist independently of contact with our universe? These are more tricky questions. I don't think science will provide an answer beyond the illusion of success. **Whether that illusion is in fact real will be a question for philosophy that we may have to face soon enough.**

Conclusion

Our conscious mind emerges from biology and psychology, requiring no further explanation, biology in turn emerges from physics, fine-tuned to suit evolution by anthropic selection from a landscape of vacuum solutions in the great path-integral of the master theory. Similarly, the master theory of physics is the collective behaviour of the inter-relationships between the logically possible worlds and our experiences of them. Existence is relative, nothing more is required.

The goals we set ourselves transcend our mere survival, yet they are accidental by-products of states of emotion that evolved to help us pass on our genes. We have reached a rare level of intelligence on a rare planet in a rare universe.

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