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# The Inevitability of Life

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## 1. Introduction

For most of human history, we have drawn an incontrovertible distinction between life and non-life. In our daily operations, the differences between these two manifestations of matter are all too apparent to think of their relationship in any other way. Even the relatively inanimate plants and fungi demonstrate that they deserve to be placed on our side of the divide if we bother to take a closer look.

However, for the past few centuries, advancements in biology and chemistry have begun to blur the line that we previously thought was quite clear. The human being is formidably complex, but from the organism to the organs, tissue to cells, cells to molecules, and molecules to atoms, we have gradually been able to piece together a defensible (though notably incomplete) picture of how each level pertains to the next. What we're left with is a handful of questions, the answers to which have consequences for disciplines stretching from chemistry to philosophy: At the lowest levels, is there any fundamental difference between the substances that form the living and the non-living? Does a coherent and comprehensive definition of life even exist with which we can draw this distinction? And do the answers we give to these questions have any bearing on how we live our lives?

I will take a first-principles approach to life, making the case that the seemingly conspicuous differences between life and non-life arise only due to the diversity of ways in which a set of physical and chemical principles manage to express themselves. In doing so, we will see that life seems to be an inevitable outcome of the laws of the universe interacting with plain, baryonic matter. I will then argue why these laws and the phenomena to which they necessarily give rise can potentially put constraints on the nature of complex, intelligent life. Finally, I will very briefly discuss the implications that the above observations have on how we understand ourselves and the universe around us.

## 2. The Second Law of Thermodynamics

Thermodynamics is a branch of physics concerned primarily with studying energy and how it behaves. Considering that matter and energy, according to Einstein's famous equation $E = mc^2$, are two forms of the same thing, thermodynamics can be said to be the study of the entire universe. However, for obvious reasons, I'm not going to be discussing literally the entire universe in this paper. Specifically, I want to zero in on the second law of thermodynamics.

The second law, in few words, states that the entropy of a closed system will always increase over time. Sounds great. But what the heck is entropy, and why does it only go up? You may have heard of entropy described in a high school chemistry class as something to do with "order" and "disorder." But, if you're like me, that's hardly helpful. Instead, all we need to imagine is a ball rolling down a hill. That's it. The second law basically states that all physical phenomena in the universe are analogous to this scenario. Equivalently, a physicist would say that all action, events, or occurrences are the result of a net decrease in potential energy. A literal ball rolls down a hill because it has high gravitational potential energy (or low entropy) at the top and low gravitational potential energy (or high entropy) at the bottom. Meanwhile, a magnet stuck to your fridge only stays there because it is going from a state of high magnetic potential (away from the fridge) to a state of low magnetic potential (on the fridge). Similarly, everything you observe daily can usually be described in similar terms. See Figure 1 below for an illustration.

There are some obvious objections that might occur to you at this point. First, I can carry a ball to the top of a hill. Am I disobeying the laws of physics by doing so? Secondly, if everything wants to be at the lowest possible potential state, why doesn't the magnet on the fridge also fall to the ground? Why doesn't everything just collapse?

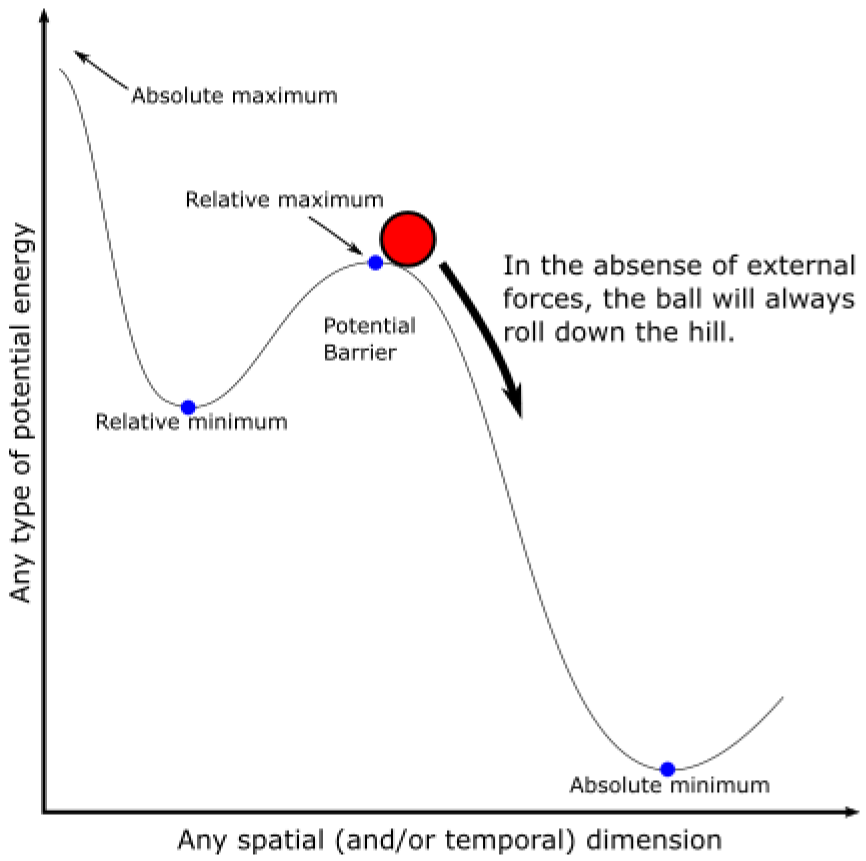

*Figure 1: A ball rolling down a hill.*

To address the first concern, I need to reference the words "closed system" which I used in the original definition of the second law. If I bring a ball to the top of a hill, the closed system would usually be defined to include me and the energy that I have stored inside of me. The second law isn't broken when I bring the ball to the top of the hill because the metaphorical ball representing the potential energy contained in my muscles rolls *down* its respective hill at least as much as I moved the literal ball *up* its hill. So, if we combine all the energy in the entire closed system into one ball-hill picture, the net movement of *this* ball was downhill even if the behavior of the constituent parts (i.e. the literal ball) didn't follow the pattern uniformly.

For the second concern, I need to address relative and absolute minima. Clearly it is not the case that all actual hills have only a top and a bottom. There can be undulations in the terrain such that you can roll a ball down a hill only to have it get stuck in a small depression before it reaches the “true” bottom (again, see Figure 1). A smaller hill which prevents the ball from falling further down is referred to as a potential barrier. For a magnet on a fridge, gravity isn’t strong enough to pull the metaphorical ball over the potential barrier created by friction, so it stays put until something gives it an extra kick. Yet another example would be a table stopping everything on top of it from falling to the floor because it acts as a relative potential minimum to the floor’s (more) absolute minimum. As we all know, it only takes a small outside force to send a fragile glass on top of a table smashing to the floor. This is just like kicking a ball over its potential barrier down the rest of the hill to the absolute minimum.

These examples further reinforce that none of this can happen spontaneously without energy coming from an outside source. The ball must be kicked, the magnet pushed, or the glass bumped, but none of them have the energy to accomplish movement on their own when they’re resting at a relative potential minimum. And even if an outside source performs this action, the net change in potential energy is always downhill, never uphill.

## 3. Replication, Mutation, and Selection: Life in the Machine

Life is notoriously difficult to define. Most definitions are based around ideas of self-replication, Darwinian evolution, and perhaps even consciousness. But not everything we typically call life demonstrates these characteristics in all circumstances. Is a sterile animal not alive? If we found a species whose genome couldn’t mutate, would it cease to be living? If we were to somehow prove that plants are not conscious, would that bump them off the list? As I have alluded to in the introduction, I will not bother to define life explicitly. Instead, I will try to explore self-replication and evolution in detail to see why they are so often connected to our view of life. The issue of consciousness is, at present, too unempirical to discuss in this section.

First, let's chase away any traditional examples of life loitering in our heads and look at self-replication on its own terms. A useful way to do so is via computer simulations—specifically cellular automata (CA). While they can be quite complex, we'll just look at the most basic family of CA which consist of a grid of squares (or cells) that can be either on (alive) or off (dead). Following some set of rules and a starting pattern specified by the experimenter, the grid changes from one state to the next throughout the course of the simulation until it is shut off. One famous example is the Game of Life invented by John Conway in 1970 [1]. For this CA, the rules are as follows:

1. Any live cell with fewer than two live neighbors dies (underpopulation)
2. Any live cell with two or three live neighbors lives on to the next generation.
3. Any live cell with more than three live neighbors dies (overpopulation)
4. Any dead cell with exactly three live neighbors becomes a live cell (reproduction)

In most cases, an arbitrary initial state will tend to simplify down to a handful of basic patterns. Some structures stay put (still lives), some are a bit more dynamic (oscillators), and some are mobile (spaceships). However, some very meticulously designed structures exhibit significantly more interesting behavior. These consist of hundreds of thousands of cells, and after about 200 million generations, succeed in in fully self-replicating. To put into perspective how absurdly difficult these structures were to manufacture, the first true self-replicator wasn't created until 2013 (by Dave Greene), 43 years after the original game was established [2].

Even more amazing is the fact that the foundations for CA and the exact strategy used to create the self-replicator mentioned above were devised by John von Neumann in the 1940s. He imagined that self-replication would require three things: a blueprint, a constructor which could turn that blueprint into a structure, and a copier which could copy the blueprint to be used for future replication of the structure [3]. See Figure 2 for an illustration.

But von Neumann was interested in more than just replication. Before the structure of DNA was known, he was already thinking about how these replicators could evolve via mutations in the blueprints. Therein lies the true significance of these structures. On its own, replication isn't all that interesting. In the Game of Life, it was clearly an achievement, but that was mostly due to the especially simple rules which make complex behavior harder to achieve. In more elaborate CA that allow squares to have more than just two states (von Neumann specifically imagined that each square could take on 29 different states), replicators had already been designed long before [3]. Once a mechanism is put in place to allow for stable mutations to be encoded into the blueprints, it doesn't take much more to allow for an explosion of complexity under the guidance of Darwinian evolution.

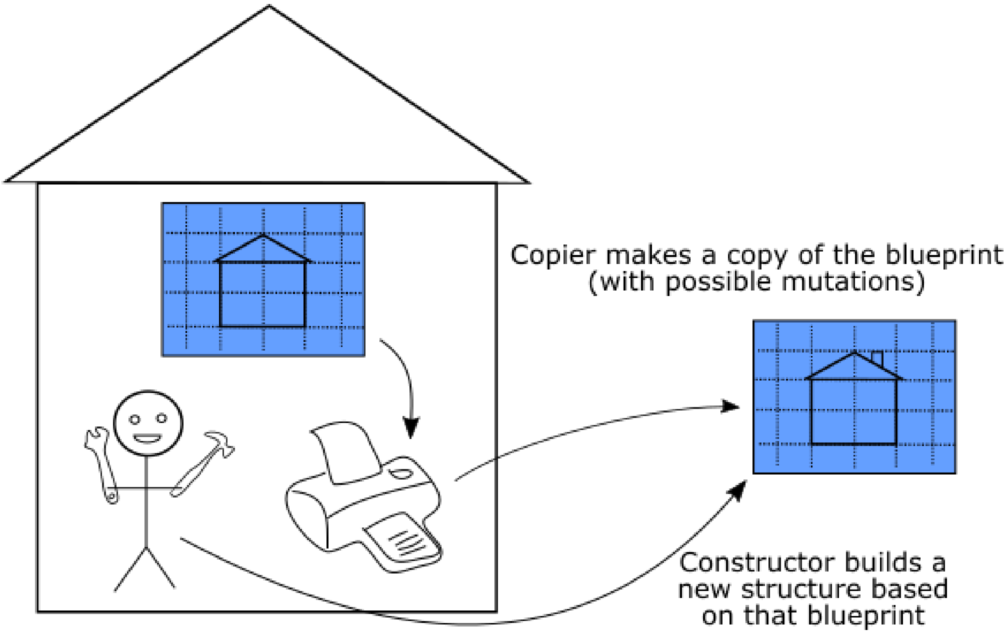

*Figure 2: A hypothetical structure containing all the pieces necessary for self-replication according to von Neumann: a constructor, a blueprint, and a copier.*

Any replicator in a CA which uses a blueprint accessible by experimenters can experience mutations through manual alterations injected by the experimenter or a bit of code designed to alter the blueprints at random. The last thing we need to arrive at evolution is an additional set of "rules" which determines which of these replicators can continue replicating. In other words, these structures would need to be subject to environmental factors which kill off structures that develop unhelpful mutations while favoring those that develop beneficial mutations. Within the CA we've been discussing, we might imagine an environment in which still lives, like a block of 4 cells, are scattered about (normally, an environment starts out blank except for what the experimenter builds). Since replicator structures (or any structure, really) are typically very fragile, such obstacles would spell disaster for most if one got in the way of the next copy. So, if we put a hundred replicators into an environment and let them evolve, the ones that run into obstacles would tend to die and fail to replicate additional copies. Meanwhile, those that survive (if any) will either have been lucky enough to have avoided obstacles or will have managed to develop a way to get around them. Exactly how they manage it doesn't really matter; maybe they'd develop a sort of membrane for protection, or maybe they'd come up with a more unique solution. Regardless, after some time, those that failed to adapt would be dead, and those that adapted successfully would continue to create more copies.

That's pretty much it. Replication (constructor/blueprint/copier), mutation, and selection are the main features necessary for evolution to take place generally. There's no further special spice to make the system work. In fact, while mutations are generally random, the underlying mechanisms are purely deterministic, like a ball rolling down a hill. Evolution is a statistical inevitability—a requirement. It doesn't matter if we're talking about patterns of squares inside a computer simulation or creatures out in the wild. Better mutations lead to more copies which provide the potential for still better mutations, and the cycle repeats. Any environment in which these ingredients exist will eventually give rise to steadily more complex and fit structures. This deterministic pattern gives rise to all of life as we know it.

# 4. Animate from Inanimate: Life in the Universe

Now we can combine thermodynamics and the principles of evolution to describe real life made of physical matter. Let's start at the big bang and tip-toe down the timeline to the point where the first stars have just gone supernova, blasting the ingredients needed for life out into the cosmos. From the remnants of previous supernovae, new stars and planets condense around gravitational potential minima. Some planets—like Mercury, Venus, Earth, and Mars—form from dense, rocky material. Once they have cooled enough to form a solid surface, a mixture of various elements and molecules gathers. Usually, this is where it ends, not dissimilar to how a "round" of the Game of Life would end if one just randomly scattered cells within the grid. The planet spins about until it's swallowed up or blown away by its parent star's supernova. But in a few cases, more interesting things can happen on its surface.

At this point, life as we know it requires water to develop. But I want to stay general. All I care about is that some sort of medium exists to provide microscopic materials the chance to bump together often and energetically. If there is sufficient energy present, the potential barrier previously keeping one atom separate from another will be exceeded, leading to a chemical bond. This is all a molecule really is: a joining of two atoms at the bottom of a mutual potential minimum. The force involved is coulombic rather than gravitational, but the same basic idea is behind the ball rolling down the hill and the formation of the planets.

Time for the tedious part. We need to wait. Remember how that replicating structure in the Game of Life took 43 years to be devised? That was with smart people working specifically toward that goal. In the real-world analog, unless you wish to imagine a creator deliberately trying to come up with a pattern that can self-replicate, we must let the random motion of the molecules take the wheel. And this would take an extremely long time (or less time plus a lot of luck). Over millions or billions of years, enough atoms and molecules will stick together into some interesting structures. Organic molecules and amino acids have been observed in clouds of dust out in interstellar space, so we know they don't need particularly special circumstances to form [4]. Experimenters have successfully generated lipids in the lab using a recipe that could be replicated in the natural world, so it's plausible that they would be floating around the primordial Earth [5]. So, what exactly are we waiting for?

We still don't know how this happened, but that's not the point of this paper. All we know is that RNA eventually popped up. RNA is special for many reasons, but it's uniquely equipped to serve the basic functions outlined by von Neumann. That is, along with some help from its environment, it can serve simultaneously as a blueprint, a constructor, and a copier. Furthermore, due to occasional accidents, copies of a strand of RNA can wind up with small alterations or mutations which get passed on to future copies. In my quest to stay general, it should be noted that it's possible that other complex molecules could serve the same role as RNA/DNA, but currently, no such alternatives have been found.

The remainder of the tale looks vaguely as follows: First, some RNA found a way to isolate itself from its environment. Since lipids naturally orient themselves into clumps that can eventually turn into spheres, it's possible that a few strands of RNA got stuck inside a ball of lipids or some other protocell and got to replicating [5]. Since RNA can serve as a catalyst to make proteins (i.e. certain molecules have a lower potential barrier to formation in proximity to the RNA), we would expect the most successful strands of RNA to evolve the ability to catalyze proteins that help it in its own replication. From within a protocell, it could accumulate helpful molecules, allowing these pieces of RNA to replicate exponentially faster. With enough time and a bit of luck, it might reinforce its surrounding shell and begin to resemble simple viruses or bacteria. And since each nucleotide that goes into forming a successful strand of RNA can't be used to form a more mediocre one, a rudimentary form of competition results in steadily more complex and crafty RNA.

I will resume this chain of evolutionary events in the next chapter. For now, I want to zoom out a bit and take stock. It may seem ludicrous that all of this could happen by chance, but over the 10 billion years or so that the universe was stewing about before life as we know it appeared, the absurdly unlikely had many chances to happen. And it only had to happen once. If successful self-replication leads to exponential growth and open-ended complexity, it doesn't take long for ground zero (the first viable molecule to serve as a blueprint, a constructor, a copier, and a vessel for mutations like RNA) to lead to a breeding ground of evolutionary activity.

Critically, this process allows for an accumulation of diversity and complexity. Any quantity of unique organisms can proliferate so long as they meet the conditions outlined above and are sufficiently fit or lucky enough to pass their information on to the next generation. And this process also holds regardless of whether we're talking about RNA/DNA-based organisms, structures in a computer simulation, or any other medium capable of carrying out the same basic processes within a given environment.

## 5. Diversity, Cooperation, Complexity, and Intelligence

"Survival of the fittest" is an unfortunate phrase which has given many people the wrong impression about evolution. In some contexts, it brings up images of ruthless and powerful creatures clawing their way to the top of the evolutionary ladder. In other situations, it can be wielded to argue why one race is superior to another—why the powerful deserve to take over and exterminate the lesser, thereby accelerating humanity toward some ideal or teleological end that natural selection was supposedly pushing us toward anyway.

But this conception of evolution leaves out two additional factors which really complete the picture. Firstly, the standard of fitness changes. Mammoths died out while elephants lived on not because the latter is inherently superior, but because the world for which the mammoth evolved changed. What was considered highly fit in the ice age was no longer fit in a warmer world. Secondly, there is more than one way to be fit even within a given context. Ants have found one recipe for success that arguably works better than our own in many ways. But, of course, humans have also found great success in the modern world in evolutionary terms. In this way, intelligence is not necessarily the paragon feature of life. It’s just one adaptation in a sea of niches that happens to have been particularly fruitful at the current moment. “Survival of the fittest” should really be “survival of the good-enough.” So long as you dodge your demise long enough to pass on your genes, as far as evolution is concerned, you’ve succeeded.

This would seem to lead us to conclude that intelligent life is not necessarily an inevitability in any given environment. The development of such complexity is contingent upon many factors that may not have turned out so favorably elsewhere. A planet pelted with an unrelenting torrent of debris from space won’t find it easy to evolve life beyond the smallest and simplest of creatures. An icy body far from its parent star may not receive enough energy to allow for potential barriers to be regularly exceeded, thereby preventing certain reactions from ever occurring. There are many hostile environmental factors which could prevent intelligence from developing elsewhere in the universe. However, so long as a possible path to intelligence is viable and the creatures exploring this path are sufficiently successful, intelligence would be expected to turn up eventually.

What does that journey to intelligence look like? Here is where I’ll pick up the evolutionary story I previously started. On Earth, we can split the timeline up with major evolutionary milestones which primarily occurred due to cooperation. RNA cooperated with the helpful molecules I mentioned a while back to achieve mutual proliferation. Once firm cell walls had been established, trapping all these molecules together, the next step was for two cells to cooperate; due to some happy accident, one cell swallowed another, but neither died. Instead, the waste products of the internal fed the external and vice versa. This is called endosymbiosis. So now we have eukaryotes (complex cells with organelles which originated as separate species). These eukaryotes then clumped together for protection and to share resources. Those that stuck together permanently passed that strategy on. Then some of those cells started to specialize, beating Henry Ford to the punch by at least a few hundred million years. This led to the development of all the major types of life we see every day. Presently, the next stage is still taking place. One blob of cells started to cooperate with its neighbors to form packs, tribes, societies, and civilizations. Humans have integrated this intense socialization into their genome more so than any other species.

This suggests that cooperation, in some form or another, is almost certainly necessary for complex and intelligent life. At its core, cooperation is a manifestation of the principle that the whole can sometimes be greater than the sum of its parts. At each stage, specialization allows for the necessary tasks of life to be carried out more efficiently and effectively than before. Enzymes, organelles, organs, and organizations are examples of specialized parts which play a pivotal role in the operation of the whole or host. On a hypothetical, life-sustaining planet, we can’t know for sure what the mechanisms behind the operation of its resident life would be. Life doesn’t necessarily have to form around basic units that we might identify as cells. Therefore, without getting immensely speculative, we cannot claim to know how cooperation would work in all cases. We can only suggest that it seems to play an important, general role in creating an organism which is efficient enough to be able to dedicate a large amount of resources to developing and running something as energetically expensive as a brain (or an equivalent computational organ).

## 6. Cooperation and Conflict in Intelligent Life

Does the total path to intelligence (from the first replicator to late stages of cooperation) allow us to speculate any further about the nature of intelligent life? I think it does, and unfortunately, its consequences aren't exactly cheery. First, I want to harken back to the image of the ball rolling down the hill in order to repurpose it for a brief definition of equilibria.

The top of a hill is an unstable equilibrium. A ball can balance there, but any slight push will send it rolling away. The bottom of the hill is a stable equilibrium where the ball can balance; any push won't do much since it'll just return to the same spot. Many cooperative contexts are unstable equilibria. As an example, look at forests. Why do trees grow so tall? They spend a lot of resources stretching up toward the sky for little gain. Wouldn't it be better if they all just stayed closer to the ground and used that energy to store more water and nutrients to help them survive dry spells and such? Imagine a scenario where all trees grow to the same height of about a foot off the ground. This could be seen as a "cooperative equilibrium." Each organism can save their resources rather than spending them on growing super tall, so everyone is better off. But then one species develops a mutation which causes them to grow a bit taller just by chance. This mutation requires the tree to spend more resources, but it can now absorb a bit more light while its neighbors are cast in shadow. Over time, the taller species will be more successful and crowd out any other species which fails to put up a fight. The result is a forest of competing organisms that must strive steadily higher to absorb enough light. The equilibrium was unstable.

The same thing happens whenever groups of people agree to follow a certain set of restrictive rules. So long as the rules make sense and everyone respects the agreement, a cooperative equilibrium is formed. But what happens the moment one person cheats? If there is no enforcement, nothing to restore the equilibrium, then everyone else will soon follow suit. This is also an unstable equilibrium. We'll revisit this topic shortly.

Let's now return to pondering the nature of intelligent life. Just as helpful mutations that change an organism's physical appearance can be passed on, mutations pertaining to behavior can be passed on in much the same way. Evolutionary psychology uses evolutionary principles along with our knowledge of genetics, brain formation, and behavior to help explain why all humans tend to exhibit certain idiosyncrasies—for example, why we're often suspicious of or even hostile toward people who don't look like us or why we smile and laugh in certain situations [6].

This area of study is quite young and full of speculation, so it's important to proceed with a healthy amount of skepticism. Since we can't do experiments pertaining to human evolution, we're forced to use what we know to tell a sort of evolutionary story that connects the dots. But just because a story makes sense doesn't guarantee its accuracy. I will focus on the first example that I mentioned above, but I will try to talk in terms of broad tendencies and small evolutionary pressures rather than absolutes. Much of behavioral evolution is extraordinarily complex and still in the process of being studied.

Restating the question at hand, why do humans tend to form close-knit units centered around family, shared characteristics, and shared beliefs while ostracizing and readily committing violence against those who are different? Surely, we'd all be better off if we put aside petty conflicts and worked together for the good of the entire species or planet! Why has evolutionary pressure seemed to select for (at least some) conflict-inducing traits rather than only pacifying ones?

To understand this phenomenon, we must first return to our genes. Each gene leads to some general effect whether in behavior, appearance, or ability. Regardless of how it happens, if that effect is somehow responsible for more copies of the gene existing in following generations, it will tend to proliferate. Aiding the survival and reproduction of the host organism is the most obvious way to produce more copies, but it isn't the only way. The fact that family members tend to share a certain proportion of their genes means that a gene can *also* be successful by helping the organism's family or any other individual which shares that gene. This inclines us to develop behaviors which favor the success of those with whom we are related or those with whom we have a high probability of being related. Since we can better put such behaviors into practice if we stay in proximity to each other, we prioritize forming social groups based on anything which can serve as a proxy for genetic similarity and proceed to behave in groupish (as opposed to selfish) ways [7].

Now imagine what this means for neighboring groups. Let's pretend you and I are members of different tribes a couple hundred thousand years ago. Any resources that your group uses are resources that mine can't. If we have any reason to covet your food stores or territory, violent conflict is an obvious way to obtain them if some other mutually beneficial relationship can't be formed. The genes in my tribe gain nothing at best and face existential threat at worst by allowing your tribe to exist beside us (and vice versa). The only incentive we have to avoid such conflict is the risk that my tribe would lose the fight. But if the odds don't seem too poor, and especially if your group is also plotting some sort of violent takeover, we would probably prefer to attack rather than sitting idle. After all, a bunch of neighboring tribes which are roughly equal in military power are in an unstable equilibrium; if one attacks successfully and grows in power as a result, it's that much easier for them to continue attacking everyone nearby until they own all the best territory in the region and have plundered as much resources as they can carry.

It follows that any similar behaviors which push us to cheat, to behave selfishly or groupishly, might be favored over the course of evolution, at least in circumstances where such behaviors have a history of succeeding. But equilibria aren't always unstable, and we clearly aren't murdering each other every day just to obtain more resources, so there's more to the story. Humans have developed at least one key method for maintaining otherwise unstable equilibria: shame. Cheating can sometimes cause the cheater to be more successful, but it's also the case that if everyone were always cheating, the group would suffer. Therefore, there may also be evolutionary pressure for groups to develop forces like shame or even justice systems to maintain order and punish cheaters. Even if we don't think we'll be caught, there's always that voice in the back of our minds telling us what we should and shouldn't do, as well as a fear (bordering on paranoia) that others will discover our misdeeds.

But what does this have to do with intelligent life in general? Aren't these behaviors mostly unique to humans? Not necessarily. Tribal conflict exists in chimps, many mammals form groups based on family, and it's plausible (though unproven) that wolves and dogs feel shame. The evolutionary principles involved are still general. Any sufficiently complex von Neumann self-replicator would be expected to evolve these same tendencies if the conditions were sufficiently similar (i.e. blueprints which influence behavior, collections of individuals that share some proportion of their blueprint, and competition over a finite supply of resources). To this end, we cannot suggest that these behaviors are universal per se, only that they have some reasonably high chance of developing in any case where the same conditions are met.

## 7. Conclusion

The ball representing the potential energy of the universe always wants to roll downhill. Any chance it has to roll to the next relative minimum, according to the second law of thermodynamics, *must* be taken. The same is true for any closed system within the universe. So as molecules on a planet stew about, they will collide and combine in any way that achieves this end, forming bonds which correspond to a mutual potential minimum. If enough energy is present at the right time and in the right configuration to push molecules over certain potential barriers, something which matches the description of a von Neumann replicator can be formed (like RNA). If this replicator can experience mutation in an environment capable of natural selection, evolution will take hold. The fit necessarily survive to become still more fit and generally more complex. This complexity is, as far as we know, primarily achieved through cooperation. In environments where it's viable, we might expect to find intelligent beings continuing to cooperate. To maintain this cooperation despite the existence of possibly unstable equilibria, they would be expected to develop certain conflict-inducing as well as some self-policing behaviors.

All laid out together, we can see this as an argument for why life is nothing more than a particularly animated formulation of matter which is bound to develop because of the universal laws which we observe. Furthermore, this leads us to the conclusion that other intelligent beings in the universe might be expected to develop traits we typically associate only with humans. No single trait we exhibit is likely an *inevitable* development in other species, but many of them could be expected to be observed if we ever happen to find other intelligent life in the universe. Indeed, we may be far less unique than one might otherwise think.

There are many caveats and details which have been glossed over, but I think the ideas expressed here make life a little less mysterious. From atoms and molecules up to the complex behavior of intelligent beings, modern science has begun to draw connections and fill in pivotal gaps. Life no longer appears to be governed by anything fundamentally separate from non-life, its unique functions just manifestations of chemical reactions which are themselves the consequence of the second law of thermodynamics. This is fascinating in its own right, but could also be seen as limiting. It suggests evolution without teleology or purpose, a lack of conscious volition. Much more study must be done to resolve further doubts, to puzzle out the true origin of RNA, to better grasp the functionality of the brain, and even to solve the hard problem of consciousness. But I am confident that these problems, to the extent that they are solvable at all, will be rendered clear soon.

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