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Life with a Different Chirality

As individual atoms begin to interact with one another and form bonds, patterns begin to arise. We see certain atoms bonding with another particular atom more often than the rest. Because all elements strive to be like the noble gasses and have all their electron shells filled, they will prefer remove or steal electrons to achieve this state. By doing this, the element will attain a positive or negative net charge. For example, neutral sodium has 11 electrons, so it exists in a $1s^2 2s^2 2p^6 3s$ state. Though, because sodium wants to be like its closest noble gas (Neon), it will prefer to remove its 3s valence electron. This results in this new sodium ion having a net charge of +1 because it now has 1 more proton than electrons (I will refer to this as 'happy sodium'). Similarly, chlorine prefers to be like argon and will try to steal an electron to fill its 3p shell. When it steals an electron, it will have one more electron than protons and, thus, have a net charge of -1 ('happy chlorine'). Now, due to the simple fact that opposite charges attract, a happy sodium and a happy chlorine, when in proximity to one another, will naturally be attracted to each other. The electrostatic force between the two will keep them bonded to each other – by what is called an ionic bond. This type of bonding, along with covalent bonding (the sharing of electrons between atoms) is one of the most common types of bonds in the universe.

The reason I went through the trouble of explaining the entire process of ionic bonding and how it is common throughout the universe is this: to provide an example of how simple laws can produce a pattern. This repetition, however, is not unique – sodium chloride is not the only atoms to bond ionically. Elements all throughout the periodic table do this, creating a wide array of molecules. Again, this is commonplace throughout the universe – multiple different forms of a single pattern can exist, just like isotopes of an atom. Carbon-14 is still elemental carbon although, it just has a few extra neutrons.

I used sodium chloride to describe ionic bonding because it is a simple, common, and easily understood example. Though, just because sodium chloride is a one of the most common forms of ionic bonding, it does not necessarily mean that it is more favorable by the universe over other similar ionic bonds. Take lithium fluoride, for example. It follows the same pattern of ionic bonding that sodium chloride does – lithium prefers a +1 charge and fluorine prefers a -1 charge, and thus, when they are close enough to one another, they will bond ionically. The reason sodium chloride is more common and appears to be favored by the universe over lithium fluoride is just a matter of environmental and abundance happenstance. If we consider the universe as our environment, sodium would make up about 0.002% and chlorine would make up about 0.0001% of the elements. Similarly, lithium would make up $6x10^{-7}$% and fluorine would make up 0.00004% of our environment. Thus, because sodium and chloride are magnitudes more abundant within our environment than lithium and fluorine, there will be a greater amount of sodium chloride than lithium fluoride. Physics doesn't necessarily prefer one over the other — there is just simply more of one pair of elements than the other. If I constructed an environment with 30% lithium, 60% fluorine and only 5% of each sodium and chlorine, lithium fluoride would clearly be more abundant than sodium chloride. The universe's apparent 'preference' to create more NaCl than LiF is not a 'preference' at all, but a simple environmental happenstance

(One could argue that the way the universe was constructed, through an intelligent design or the big bang or what have you, is not happenstance at all, but a carefully constructed or an imminent structure that can exist in one way and one way only. Though, because we do not know how or why the universe came into existence and why we have the laws of physics that we do or the elements we do, I am considering all the specific conditions of our particular universe a happenstance.)

Again, I have a specific reason for explaining this abundance difference between the two molecules. I am using this example as another analogy as to how the universe and the laws of physics themselves can be indifferent towards certain things.

Let's take a quick step back and summarize the overarching meaning of these two analogies I have provided. The first (ionic bonding) shows how some basic laws of physics can cause more complicated patterns to arise that can become very commonplace throughout the universe. The second analogy (abundance of molecules) shows that the universe and the laws of physics, though they produce patterns, do not necessarily prefer one form of the pattern over the other – one pattern may rise to be more common than another solely due to environmental parameters.

With these ideas laid out in front of us, let's finally tackle the topic of this essay: Could life elsewhere in the universe make use of a different chirality than life on Earth? Basically all life on Earth is composed of L-chiral amino acids. Though, I do not believe that this prevents life elsewhere being D-chiral.

First, I will explain chirality. In short, it is the geometric property of a structure such that it and its mirror image cannot be superimposed upon one another. A good example of chirality is shoes. Your pair of shoes are (most likely) identical to one another, however no matter how you orient the two, they can never be superimposed upon one another such that their structure match identically. This 'handedness' of structures produces multiple different definitions: When shone in a polarized light, if the structure rotates to the left, it is deemed 'levorotatory' (L) and if it rotates to the right it is called 'dextrorotatory (D); Chiral structures are isomers – which means the structures are made of all the same components, but how they are organized is different; The non-superimposable mirror image of a structure is its enantiomer; and If a mixture has equal parts L and D it is called racemic.

Now that we know what chirality is, why is it important? The first and probably most outstanding reason that chirality is important is that basically all forms of life on earth is constructed of L-chirality. This means our DNA, amino acids, chemical receptors (and thus the chemicals they receive) all possess the same L-chirality. Going into a more specific example, which I have taken from source [3]: If one were to take 50 monomers, each of them able to possess both a L and D-chirality, and you were to form a chain 50 monomers long, there would be a whopping 2^{50} possible distinct configurations. This vastness makes it nearly impossible to duplicate anything. It goes without say that, if duplication were not possible, Earth would look very different. Quoting directly from [3]: "*There is only one way to be sure of obtaining in each duplication a compound identical to the model: using only one enantiomer of each amino acid, always the same*. This condition is scrupulously followed by the living and we see that, without chirality, life would not be able to reproduce or even simply exist."

So, we can directly answer a few questions based on the info from the previous paragraph: Could other forms of life elsewhere in the universe make use of *both* L and D-chiral compounds. The math seems to indicate 'no.' The amount of added complexity that being dichiral would make the formation of life, it is (basically) statistically impossible for life like this to exist.

Now let’s tackle the other scenario: life existing with D-chirality instead of L-chirality. To (finally) answer the question: Yes, I believe that life elsewhere in the universe could exist making use of only (or very nearly) D-chiral amino acids. As I explained in earlier, common patterns can arise throughout the universe through the application of basic physical laws. Chirality is clearly one of these common patterns. Under basic physical laws, there is nothing preventing amino acids from being L or D-chiral – hence why both possibilities exist. So, we can make the assumption that, because the laws of physics are invariant throughout the universe, there is no reason that our place in the universe, or anywhere else should not be able to produce both L and D-chiral structures. If we take this to be true, then why did life on Earth form using only L-chiral amino acids? Applying the second analogy I described earlier, it was probably due purely to happenstance. Just because all life on Earth is L-chiral does not mean that it is the only way life can exist. It was likely just due to a flip of the coin that life on Earth formed with L-chirality. The very first form of life on earth may have made use of it for no reason in particular, and it just blossomed from there. If life could exist and thrive using only one chirality, why would it evolve to change something that did not require changing? Thus, I believe that life elsewhere in the universe could very likely form to be D-chiral, and the reason they are that way is nothing more than pure happenstance.