A Brief Look at the Probability of Life Arising by Chance

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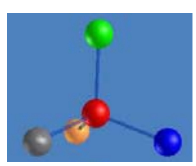
It is easy to recognize that the probability of life developing by the random chance of biological evolution is an extremely low probability. But when you consider the vastness of the universe and its approximately age of 15 billion years, this idea can be conceived as feasible by many. But is it really?

The late George Wald states in 1954,

> "The important point is that since the origin of life belongs in the category of at-least-once phenomena, time is on its side. However improbable we regard this event, or any of the steps which it involves, given enough time it will almost certainly happen at least once. And for life as we know it, with its capacity for growth and reproduction once may be enough.
>
> Time is in fact the hero of the plot. The time with which we have to deal is of the order of two billion years. What we regard as impossible on the basis of human experience is meaningless here. Given so much time, the "impossible" becomes possible, the possible probable, and the probable virtually certain. One has only to wait: time itself performs the miracles."[1]

However, the more we study biology, the more complex the systems become and the idea of biological evolution is challenged. Probabilities do have limits and these limits are based upon the finite amount of time and the finite size of the universe. Let me give you an illustration. Let's say you dropped 30 coins randomly and you wanted to get all heads. The probability would be easily calculated since there are two possible choices and there are 30 coins. The probability is 1 in 2^{30}, or 1 chance in approximately one billion. Although the probability seems to be very small, if you had thousands of people dropping coins for weeks, you would probably succeed. But what if you were challenged to accomplish this task with only 10 people in 10 minutes? Your perspective may change considerably. Assuming a person can gather the coins up and drop them 10 times a minute; the group could only make about 1000 attempts. By dividing these numbers your probability would be one chance in a million, which is not something I would gamble on.

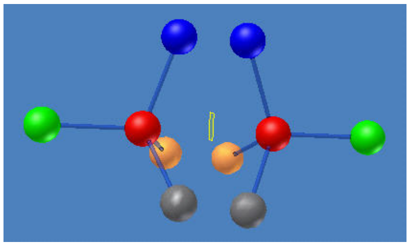
I chose the example of coins because there is a very similar illustration in biology. There are 20 amino acids that are used as the building blocks of proteins. These amino acids have a carbon atom in the middle which is refer to as the alpha carbon (red).



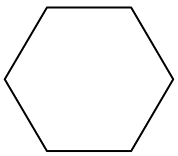
[1] George Wald (late Professor of Biology, Harvard University), "The origin of life". Scientific American, vol. 191 (2) august 1954, p. 48.

This alpha carbon has four bonds that connect it to four different molecules. At one bond will be a carboxylic acid (-COOH)(blue). Another bond will be an amine ($-NH_2$)(green). A third bond will be a hydrogen bond (H)(orange). And the fourth bond will be another carbon side chain (R)(gray) which contains the rest of the atomic structure. The carbon side chain can be quite complex and is what distinguishes one amino acid from another.

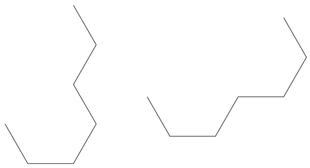
When you construct 19 of the 20 amino acid in a 3-D environment, you will find that each of the amino acids comes in two forms. This chiral affect that creates these two forms for each amino acid are essentially mirror (yellow plane) images of each other.



They are commonly referred to as left hand and right hand amino acids. Since the left hand and the right hand amino acids are identical in terms of the atomic structure, all of their physical properties are exactly identical. When Stanley Miller performed his experiment in 1953, he created amino acids, both left hand and right hand in a 50-50 mixture. This is what would be expected in a totally natural process. However, the amino acids used to make up proteins in living organisms are only found in the left-hand form. A single right hand amino acid introduced into the system would change the folding characteristics and create problems causing the protein not to function as required. This can be simplified and illustrated by creating a 2D model. Each line represents an amino acid and each bond bends to the left 60 degrees. With six lines you would create a hexagon every time.



But if you insert a single right hand bend, representing a right hand amino acid anywhere in the six bonds, you would not be able to consistently control the outcome.



If you expand this to a 50-50 mixture of right and left hand amino acids and increase the protein to 1000 amino acids in a 3D environment, you can see that the DNA code for a protein would never be able to consistently produce the same protein molecule, and life could not exist.

To simplify the probability calculations for a protein, I have excluded the specific order of amino acids that is required to create a designated protein. To explain the reasoning, let's consider the probability of a monkey typing a 5 letter word like "house", with each letter representing an amino acid. In this scenario, not only are the right and left hand properties of amino acids important, but the order of the amino acids. The probability would be 1 chance in 26^5 or 1 chance in approximately 12 million. However, there are many legitimate 5 letter words that the monkey could type, and when it comes to proteins, it would be difficult to distinguish between legitimate patterns or not. Even though this order reduces the probabilities much more significantly than just figuring left hand amino acids, I have chosen to be very conservative and not include the order in the calculations.

This narrows the focus to the fact that all proteins must consist of all left-handed amino acids. Similar to the example I gave with dropping coins, there are only two choices, left and right hand amino acids. So to calculate the probability of creating a single protein of 1000 amino acids would simply be 1 chance in 2^{1000}, which comes out to a probability of 1 chance in 10^{301}. This may seem like a very slim chance, but many would argue that the universe is so vast and there's so much time that it is not an unreasonable probability. However, the universe and time is finite, so let's factor this concept into the equation.

As in the example with the coins, we had multiple people working with the limited amount of time to try and get the results. However, since we are working at the atomic level, instead of people we will substitute atomic reactions. The goal is to calculate the maximum possible number of atomic reactions that can take place in the universe at a given point in time. In physics, the laws of gravity are well understood and we can use this to calculate the mass of the sun in grams ($2 \times 10^{33)}$. In chemistry, we know the number of atoms in a mole, based upon Avogadro the number is 6.02×10^{23}. Since one mole of hydrogen is the equivalent of one gram, we can conclude there are 1.2×10^{57} atoms in the sun. In other words, we can conclude that at any one instant in time, we have a maximum number of possible reactions within our solar system.

It may be appropriate to mention that the combined mass of the planets is negligible compared to that of a sun, which is considered an average star. Since NASA estimates that there are about 200 billion stars in our galaxy and the universe consists of about 200 billion galaxies, we can extrapolate the number of atoms in the entire universe.[2] Multiplying the number of stars in our universe (4×10^{22}) by the mass of an average star, our sun (1.2×10^{57}), we can estimate the number of atoms existing in our universe to be 10^{80}. So we can conclude that at any one instant in time we have a maximum number of possible atomic reactions. Just like the limit of 10 people we placed on the coin illustration, the limit of reactions is 10^{80}. Now all we have to do is factor in the limited time.

[2] http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970115.html

In the coin example, the time was limited to 10 minutes. The time required to create a protein by random chance is limited to 15 billion years. Let's first begin by asking what is the minimum time required for an atomic reaction to take place and how fast can this occur. Since our goal is to establish an upper limit, I am going to go way beyond what is feasible. The fastest frequency known to man is the cosmic wave which can oscillate at 10^{45} cycles per second[3]. Since this is the fastest frequency known, we can assume that there can be no chemical reactions that occur faster than this. We also know that there are 10^{17} seconds in 15 billion years. By multiplying these two numbers together (10^{63}), we can get the maximum number of reactions that can take place in 15 billion years.

By multiplying the maximum number of possible reactions (10^{63}), with the maximum number of atoms (10^{80}),, we can conclude that there are (10^{143}) possible reactions in the universe over 15 billion years. Therefore, we can conclude a probability smaller than 1 chance in 10^{143}, will not happen.

When we take the probability of creating a single protein of left-handed amino acids (1 chance in 10^{301}), and figure in the maximum possible reactions in the universe over 15 billion years (10^{143}), it will yield a probability of 1 chance in 10^{158}. We can conclude that the random chance of biological evolution to create a single protein anywhere in the universe over 15 billion years is essentially zero. The probability can be compared to a monkey being given only one chance to type this sentence.

As I mentioned earlier, I did not figure in the probability of the specific order that is required to create a single protein. When we consider the above example of 1000 amino acid to make a protein and that there are 20 possible amino acids in living organisms, we could calculate the probability to be 1 chance in 20^{1000} or 1 chance in 10^{1300}. This makes the consideration of biological evolution by random chance even more absurd.

Not only are all proteins made up of left hand amino acids, but we have a similar situation with the DNA. The frame of the DNA molecule is made of alternating sugar and phosphate molecules. Like amino acids, the sugar molecule has an alpha carbon in the middle, creating two forms. However, all sugar molecules in DNA are made up of the right hand form. This is fundamental to giving the DNA its characteristic spiral twist. A left hand sugar molecule would cause the spiral to twist back in the opposite direction at that bond. Since there are approximately 3.1 billion base pair in a single human cell, there will be 3.1 billion right handed sugar molecules on each side of the DNA chain. If the probabilities mentioned in this paper are not sufficient to prove biological evolution is impossible, consider the probability of the right handed sugar molecules in DNA. The DNA in a single human cell coming into existence by random biological evolution is 1 chance $2^{6,200,000,000}$. That translates to approximately 1 chance out of $10^{2,000,000,000}$.

[3] http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray_spectra/background-em.html

Sir Fred Hoyle states, “Once we see, however, that the probability of life originating at random is so utterly minuscule as to make the random concept absurd, it becomes sensible to think that the favourable properties of physics on which life depends are in every respect deliberate.” . . .

“It is therefore almost inevitable that our own measure of intelligence must reflect in a valid way the higher intelligence to our left, even to the extreme idealized limit of God.”[4]

[4] Sir Fred Hoyle (English astronomer, Professor of Astronomy at Cambridge University) and Chandra Wickramasinghe (Professor of Astronomy and Applied Mathematics of the University College, Cardiff), “Convergence to God”, in Evolution from Space, J. M. Dent and Sons Ltd., London 1981, pp. 141 and 144.