GENESIS OF LIFE ON EARTH

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> Damyata: The boat responded Gaily, to the hand expert with sail and oar The sea was calm, your heart would have responded Gaily, when invited, beating obedient To controlling hands
> I sat upon the shore Fishing, with the arid plain behind me Shall I at least set my lands in order? London Bridge is falling down falling down falling down Poi s'ascose nel foco che gli affina Quando fiam uti chelidon—O swallow swallow Le Prince d'Aquitaine à la tour abolie These fragments I have shored against my ruins Why then Ile fit you. Hieronymo's mad againe. Datta. Dayadhvam. Damyata. Shantih shantih shantih
>
> T. S. Eliot, "The Waste Land" 1922

Around 4.6 billion years Earth forms. We have fossil record of life from 3.5 billion years ago, these cyanobacteria that produce oxygen. The oceans have roughly 38,100 Gigatons of carbon. We can use this to estimate carbon density in the ocean, and assume it was roughly the same 4.6 billion years ago. Then we can compute the probability p that on a given day a single cubic meter of ocean has a covalent bond formed between organic compounds due to sunlight. Daily the energy of the sun is 3.65 million exajoules. It is a fairly clear model we can present which shows that covalent bond formation in Earth's oceans by organic molecules due just to sun's energy is such that given sufficient time almost any reasonable size organic molecule will have some proportion in the ocean in 1 billion years. In particular, Self-Replicating RNA will be available after some time. This is our almost sure story of Genesis of Life on Earth provided SR-RNA is actually considered living. They replicate so this is a Genesis of Weak Life on Earth. After that development of life follows a new trajectory and that is a separate story.

What is special about our story of Genesis of Life on Earth–besides it being true quite clearly–is that it is extremely simple and extremely inefficient. Every possible organic molecule with sufficiently low complexity is produced in Earth's ocean. But

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this is the realistic model. The exquisite precision and specificity of life is a more sophisticated development.

1. Density of Carbon in Earth's Oceans

The total volume of Earth's oceans is

$$V_{oceans} = 1.335 \times 10^{18} m^3$$

The total amount of carbon is

$$m_{carbon} = 38100 \times 10^{12} kg$$

The density of carbon atoms in a unit cube is

$$\delta = 28.54 g/m^2.$$

This is the actual realistic density of carbon in Earth's oceans. This includes all carbon organic compounds. This density is the key to understanding the probability of production of organic compounds in the oceans. In other words, the probability that in a given m^3 that two carbon-containing organic molecules will produce a covalent bond depends on $\delta = 28.54 g/m^3$. This is a trivial computation from the mathematical point of view, but it is an enormously important parameter that controls how quickly life will form or not for realistic science.

2. Probability Two Carbon Atoms Near Each Other

Carbon bonds are 120-150 pm in length. Given 2 carbon atoms in a cubic meter, their probability of being next to each other can be estimated as

$$p_{2c} = \frac{140^3 pm^3}{8m^3} = 1.75 \times 10^{-35}$$

Now we will have 28.5 g of carbons. Carbons are 12.0107 g/mol. So the density in moles is

$$\delta_{mol} = 2.376159 mol/m^3$$

Thus we can estimate the probability of some carbon atom being close to some other carbon atom to be

$$2.376159 A_0 p_{2c} = 2.5042 \times 10^{-11}$$

This is imprecise but being good scientists we don't worry about that now and instead focus on plausibility of the numbers as a whole.

What is the probability that two carbons are close and there is some photon from the sun producing an ionisation and a covalent bond formation for any two carbons?

Let's estimate this as a fraction of sun's energy available for the cubic meter. We have energy per volume of 3.65 million exajoules for 1.335 billion km^3. The energy available for the cubic meter for the day is

$$e_{cube} = 2.734 \times 10^6 J$$

Now let's say 20% of the energy is high enough energy to ionise the carbons, that's effective energy

$$e_{highcube} = 5.47 \times 10^5 J = 3.4175 \times 10^{24} eV$$

Now carbon ionisation energy is known to be

$$i_{carb} = 11.26 eV$$

Let's write the available energy in carbon ionisation energy units.

$$e_{highcube}/i_{carb} = 3.0352 \times 10^{23}$$

Let's simplify and assume that this many photons are uniformly distributed in the box for the day. It's not exact, but it's approximately good. Then for any $140pm^3$ region we will have

$$q = 8.33 \times 10^{-7}$$

photons that can do the job of forcing the covalent bond.

This then gives us a bond formation probability of

$$pq = 2.5042 \times 10^{-11} \times 8.33 \times 10^{-7} = 2.11582 \times 10^{-17}$$

That's the probability per day of a carbon covalent bond formation. Now let's sum over the all the volume of the ocean.

$$p_{oceancovalent} = 2.11582 \times 10^{-17} \times 1.335 \times 10^{18} = 28.246$$

That's really an expectation value of the number of bonds that will form per day across the ocean.

Now we have the situation that around the oceans, every day 28.246 covalent bonds form. We can then repeat this for $T = 3.65 \times 10^{11}$ days. The expected number of bonds that formed is

$$B = 1.029 \times 10^{13}$$

Then we have a random set of molecules with B covalent bonds and then we can query whether this will produce one of the molecules that we consider are living.

3. Extremely Simplified Probability Model For Organic Compounds

Here we try to get a feel for probability models of organic compounds by simplifying the model to unrealistic situation. Later on we can return to produce a realistic model.

- A random new covalent bond is associated always to forming of RNA/DNA compounds A, T, G, C, U. We pretend only carbon matters and ignore the rest.
- Each new covalent bond has an 1/5 probability of belonging to one of A, T, C, G, U.

Our model gives us $N = 10^{13}$ covalent bonds and we want to make sure that the probability is good that longer chains will form.

This is too few to force longer chains of organic molecules to form since the covalent bonds could just form between single carbon fragments.

We need to think harder here.

4. Case of Sun Always Ionises Carbons and 10 Times Bond Length Is Enough For Covalent Bonds

We consider a relatively optimistic scenario here, where the sunlight always ionises the compounds of interest and 10 times the bond length is sufficient for covalent bond formation.

On day $t = 0$ we have probability of $p = 10^{-11}$ for covalent bond formation per cubic meter. We have volume $V = 1.335 \times 10^{18} m^3$. On the day $t = 0$ we expect $N = 10^7$ bonds to have formed, and these are all $C - C$. Then let us ignore the rest of the cubes and concentrate only on these compounds. Now we use 10 times the bond length, i.e. 1540 pm as the radius and assume that if any of the other carbon compounds are in this radius, it will be ionised and bond will form. The probability of this is:

$$q = (1540 \times 10^{-12})^3 \times A_0 \times 2.376 = 0.005226$$

The first is the radius cubed, the probability of another compound being close, and the Avogadro's number is the additivity of probabilities. This is very valuable.

Now if we just focus on the compounds that began with a covalent bond and let time pass, then the expected length of the same compound in time T is

$$L = q * T$$

and the probability of success is Bernoulli q for adding length. This will certainly give us compounds of length $L = 5 \times 10^5$ in $T = 10^8$. Similar argument will produce $N = 10^7 + 10^7 + \dots$ of these compounds and we will be able to saturate all known long organic compounds.

The assumption of 10 times the bond length for covalent bonding is realistic.

What is not realistic yet here is that sunlight always ionises the appropriate nearby compound.

At this point we see clearly that the crucial point of Genesis of Life is precisely the ionisation capability of sunlight in a cubic meter of ocean water.

5. Sun's Ability For Photoionizing carbon Atoms

We'll use the Stefan-Boltzmann law which will give us the probability distribution of wavelengths of sun's photons. It's a blackbody spectrum with $T = 6000K$, and we need to get the probability near wavelength 110 nm, short enough to ionise carbons. We need to calculate the probability that some of these high energy photons hit some small part of the meter cubed.

We're still fumbling our way to gain sense of the numbers. I could just use left tail probability of the blackbody spectrum, and get probability that wavelength is lower than 110 nm (energy high enough to ionise carbon) is $p_{highenergy} = 7 \times 10^{-4}$. This is still not right, but we can get some sense of the numbers. Plugging this as the sunlight will ionise probability, we will have

$$p_{bondforms} = 3.5 \times 10^{-7}$$

Then we will have expected length in $T = 3.65 \times 10^{11}$ days to be

$$3.65 \times 10^{11} \times 3.5 \times 10^{-7} = 127750$$

So this will definitely serve for our Genesis of Life in a billion years because these Self-Replicating RNA and other simpler 'living molecules' are within range. What we are slowly moving toward is a sense of coverage of all organic molecules provided by sunlight and ocean. This looks quite optimistic now that Genesis of Life will be explained by long period of covalent bond formation from sunlight.

6. Experimental Self-Replicating RNA

We do not claim that any particular self-replicating RNA was the first to occur in early Earth. This is nice work showing that self-replicating RNA can be demonstrated in lab [1]. This or any other sufficiently small RNA would be reached by our process.

7. We Stop When Our Unique Insights End

My original problem with various ideas of origins of life was that I was not compelled by any of the accounts of 'spontaneous chemical beginnings' at all. They seemed to me missing some fundamental sense. My new insights was to see all the oceans of Earth as becoming ready to bear life over a long time with the efforts of sun bombarding the oceans for millions of years without respite. It is the holistic view that produces a large volume of organic molecules without purpose, without precision, without life, and without efficiency. What gives substance to my theory of abiogenesis is the *abundance* that sun's energy produces in variety of purely inert dead purposeless organic molecules. And I did have the sense that I would be doing something different than the biologists because I sensed that biologists are extremely tied to extremely special qualities of sophisticated processes of life.

To the extent that it is really right that structure of certain RNA molecules is sufficient to make them *living*, in the sense of replicating etc. then I had new insights about how these could form by pure vastness of oceans, a good density of carbons, and white sunlight for day after day of huge volume of sunlight for hundreds of millions of years. Once that cascade begins with purely molecular life, then the curtain falls and a new story begins, the 'invasion of the self-replicating RNA' like space invaders in the land of the dead inert organic molecules. I am not as strong with intuition about what happens afterward, so I will stop when life begins as molecules that replicate and others with stronger sense can tell the rest of the story of life on Earth. I then skip past all the really fascinating things and return to my beloved people, the human race, and our peculiar nature. Yes fishies with eyes poking out many meters away poking out from the bottom of the Pacific and quite certain of their superiority over humans are fascinating, truly fascinating, but I'm returning to more comfortable territory next.

References

[1] Tracey A. Lincoln and Gerald F. Joyce, Self-sustained Replication of an RNA Enzyme, Science. 2009 February 27; 323(5918): 1229–1232