Environment and Selection solve Monod's Problem

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Referees: Wickramasinghe and Joseph. This is not worth writing unless it is looked at and questioned by them. I think that others would be interested in seeing this too, and that is why I am offering it to you this way.

An email from Cosmology Journal invites a commentary. In it is a statement from Wickramasinghe and Joseph “it requires at least 382 genes to sustain life”. The origin of life is a systems issue, though it is implemented by chemistry. This note focuses on system issues that show the statement to be incorrect.

The fundamental aspect of this problem was stated by Monod (1971). In simple form it is:-
The selection of organic molecules in life is by enzymes. Enzymes are shape fitting proteins actuated by Brownian vibration. Enzymes are so complex, containing so much information, that they can only be produced by genetic machinery. The machinery is operated by enzymes. Therefore enzymes are required to produce enzymes.

If all of this were correct, life could only have been created by a miracle, such as Hoyle and Wickramasinghe’s (1982) Boeing 707 from a junkyard by a tornado. And the Big Bang is the miracle of miracles in science, and so life must have been part of that miracle. The purpose of this note is to demonstrate, by example, the fallacy in Monod’s argument, and to offer a sketch of a process that could produce an organism with a single gene and so be able to evolve into a multi-gene organism by Darwinian processes.

Because enzymes are co-dependent now, that is no evidence that they originated that way. Breaking into this worm-can of misunderstanding requires both a definition of life, and an understanding of evolution. The understanding comes from Hillaire Belloc’s statement “If a thing is worth doing, it is worth doing badly.” And we add, “Evolution will fix it up.” It is as a result of evolution that life could arise through a bootstrap process. And because, in life, the transformation needs the initial process, there is usually a molecular relic that allows us to trace the development. The growth of information, lowering of entropy, is through the step by step choices of processes, and the preservation of choices by natural selection, which need not be genetic selection, see e.g. Szostak, Bartel and Luisi (2000).

The definition of life presents many problems – Astrobiology Journal (2010) devotes an issue to it. Here we start with Oparin's requirements (Eigen 1971) that life uses reproduction, metabolism (growth and self-repair) and mutability. The processes of reproduction and metabolism can be seen in non-living entities. It is the mutability that represented the change from non-living to living entities. Non-living entities can sometimes make a single choice, e.g. to add a molecule to a crystal or not. Living entities can make multiple choices, and mutability can modify choices. Some human produced devices can make multiple choices too, but we can conceptually distinguish between human technology and life.

Dissipative systems, both non-living and alive use the energy flow and materials cycled in the environment together with the choices of the entity, to produce the processes of reproduction, growth and repair. It is the energy flow that permits order to be created. Yet despite living organism's optional responses, a change of environment usually kills organisms, because they have developed to take advantage of energy and materials in specific forms, and to be vulnerable to it in other forms.

The oldest objects we know on and of Earth are zirconium silicate crystals, zircons (Wilde et al. 2001), where the cores are as much as 4.4 Gy. old. The reason that we can still find them despite erosion is that they grow, repair and produce copies of themselves. And the oldest part is usually on the inside where it is most protected against erosion. Crystals are entities that can make a single selection. They choose which molecules will join their structure and which will not, when they are in an appropriate, usually fluid, environment. That is sufficient to grow, to repair fractured surfaces, and when the environment breaks crystals, the two parts can both grow separately, and so the crystal has reproduced. This example indicates that the environment can sustain an entity which makes a single choice. Therefore Monod's analysis was incorrect.

A single gene organism can also be sustained this way. The environment takes care of growth. Growth takes care of the material for reproduction. One gene, a selection initiator, is needed to operate the transfer of information during reproduction. The primary requirement is an environment initially rich in a diverse array of organic molecules, and energy flows such as radiation from the Sun, and heat from the interior of Earth.

Mutability requires two aspects, diversity and selection. Diversity had to exist before selection so we take it first. Most elements can make a relatively limited suite of molecules. Carbon's four valence electrons can adopt many forms, including being tetrahedral, planar, or bunched with 2 or 3 linked to another atom. This diversity leads to carbon compounds providing more options of shape and linked functional groups, sometimes multiple functional groups, than any other atom. This potential diversity was described by Urey as "Beilstein", the catalog of organic molecules, when he was asked to predict the products of the Miller-Urey experiment. However, he neglected to consider the effect of liquid water in the apparatus. Insoluble products went out of solution as a brown tar, and the remaining products had a substantial similarity to the ingredients of life forms.

Water had started the second process, selection. Carbon compounds are hydropathic. Some avoid contact with water. Others prefer contact with water. And yet other amphiphilic ones choose to make a boundary with water. Interaction with water provides a first selection of carbon compounds. And it explains how water became a requirement for terrestrial life. Also the process likely depended on the distillation of the water through the atmosphere, because early membranes likely required a neutral pH.

The remainder of the selection principle requires phosphorus. Phosphorus can form a pyrophosphate that energizes condensation reactions, the linking of carbon compounds with the elimination of water. Zhu and Szostak (2010) explain how this process can strengthen vesicles, the naturally produced units of amphiphilic carbon compounds in water. Further they show that linking of the phosphorus to create phospholipids can permit the vesicles to reproduce.

We now encounter one manner in which evolution works. It takes parts and uses them for different purposes. The phosphate is linked to a series of processes of increasing complexity that could make a transition to a single gene organism that could then evolve by a Darwinian process. At each state the product needed to be sustained, and the detailed understanding of that sequence and sustaining chemistry, and its required place of origin, will when developed, become the explanation of the origin of terrestrial life.

The transformations of phosphate seem to have required the following steps. Phosphate acquired a sugar so as to provide OH and H bonds to produce condensation reactions where one of these ingredients was missing. This compound then acquired one of two bases, one that allowed condensation reactions to occur within and the other just outside a bilayer. There was an advantage in condensation reactions producing multiple-linked molecules, polymers. They could link through bilayers to assist other molecules to transit, and they could strengthen membranes. The link across bilayers also allowed the proto-organisms to take advantage of the electric potential across the membrane occasionally to re-energize the base-sugar triphosphate such as ATP- though not well (remember Belloc).

The doubly linkable molecules were amino acids, and the product of linking them were crude pre-proteins. They used all kinds of amino acids and they were not even chiral. Their location selected hydrophobic amino acids inside the bilayer, and hydrophilic ones outside. From the genetic code today we can recognize that the first selection used Uracil as base and the second used Adenine.

Thus there were linkers, molecules like ATP, but as yet the genetic code consisted just of ATP selecting and linking hydrophilic molecules and UTP selecting and linking hydrophobic ones. To make a cross link required both working together. So through this, AU became a start code, and UA stopped the process. They still do, as part of 3 letter codes. Next in looking at the genetic code today we recognize that the linkage required a change from ATP and UTP to AMP and UMP and this has persisted until today. But though a crude code could help these protocells survive, by building trans-membrane proteins and other early structural proteins, the code could not yet reproduce itself.

That required the formation and splitting of a short "ladder". That step had to be simple, because it had to be sufficiently probable to have occurred in a short while, because all the time the evolution of life was needing biomolecules which were being degraded, though perhaps stored on ice on the cold young Earth. It was only when life had progressed to a point that it had multiple genes that biomolecules could be built or repaired. Fortunately we know that a 5 nucleotide unit gene can self-copy (Turk et al. 2010). It required GMP to enter the linked units.

When one analyzes the way that nucleotides link, one realizes that the chiral component of nucleic acid is the ribose, and it is probable that mixed chirality sequences would not reproduce. But then, ~1/16 of 5-unit linked nucleotides will be monochiral, and that is not a major obstacle, nor is getting a 5 chain nucleotide sequence correct , a 1/1024 probability, nor even these combined. But the probability of selecting one chirality as compared to the other raises the natural ratio of chiral types to the 5th power, and makes it probable that one would find the same chirality in life as in the meteorites.

The process of developing life was clearly complex. And this note has only focused on production of an RNA + structural protein + membrane world, up to the point where a single gene exists. At this point there was a minimal 2-unit genetic code that needed to become 3 units, and to be transferred to DNA. There was, that far, no ribosome, no good ATPase, no Krebs cycle. None the less the organisms would grow and reproduce in a favorable environment. They could become a basis for evolution into current life.

The development of enzymes was also a slow development of improvement by addition. The first gene was also an enzyme, a ribozyme. Further development could occur either by making ribozymes, or by RNA coding for protein enzymes. The advantage of ribozymes is that they needed fewer molecules to make a large structure. The disadvantage is that amino acids have more diversity and can make a better fit. Some tasks used one, some the other. It was the transition to DNA that made manufacture of long chain amino acids relatively error free. Only then could the current enzymes start to evolve into their current co-dependent state.

This note does not propose a unique path to life. It is merely intended to show that there is a path. Current evidence does not require life to start with multiple genes, nor go back to the Big Bang, nor even to start off the Earth. More detail on this particular path can be found at http://www.youtube.com/watch?v=3dtswy9GMyM.

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