The Root of the Tree of Life: The Universal Ancestor

This paper is about a new model of the common ancestor of all life on earth proposed by Dr. Carl Woese in 1998 [1,2] to support new experimental evidence which indicates that the earliest life form was not a well defined entity in phylogenetic trees. I have selected the topic because it provides an interesting insight into the origin of life on earth.

1. Introduction

Every living creature has its parents. Each of the parents also has its parents as a generation before it. Theoretically, by running backward in time for many generations, the phylogenetic trees of these living creatures show three large domains i.e. Eukarya (Animals, Plants, Fungi), Bacteria and Archaea (Living organisms living in extreme environment). Running back further the three domains would merge into a single entity expected to be the common ancestor of all living creatures. This is a simple picture for anyone who has just learned about phylogenetic tree might have in his/her mind. It gives us some ideas about the origin of life and how it came about. Is this the correct picture? How much do we know about our common ancestor? How did it evolve and emerge as the three domains of life?

Phylogenetic trees from recent experiment showed that the universal ancestor first branched into Bacteria and Archaea and then later Eukarya branched off from the Archaea. While experiment done on some different genes showed a different phylogenetic tree that has the Bacteria and the Archaea first branched from the common ancestor and then the Eukarya branched off from the Bacteria! indicating that there is no unique phylogenetic tree to explain such all the experimental results. Dr. Carl Woese think that "Lateral Gene Transfer", the process which genes are exchanged directly among organisms and has been recognized as a secondary evolutionary mechanism, may be the primary cause of the inconsistent phylogenetic trees. This led him to proposed a new model of "the Universal Ancestor" to support the experimental result and describes what the common ancestor was like and how it evolved. The model is called "The Genetic Annealing". It is described by making analogy with the "Physical Annealing System".

2. The Genetic Annealing Model

Consider a "Physical Annealing System", it starts with a system of atoms at a temperature so high that no stable structures can form. The system then cools down slowly. During this cooling, some structures form, dissociate and reform. Some of them may be stable enough to crystallize. As the temperature continues to drop, less stable structures start to form. The more stable structures grow then becomes even more complex.

By making an analogy to the system above, the "Genetic Annealing System" started from a community of primitive cells called "Progenotes" which consisted of short mobile genes and other basic chemicals necessary to sustain life. This communal ancestor is nothing like modern cells. It is very simple in every aspect. It probably had no cell wall. Its subsystems were less complex. Each cell

was more like a bag containing small genes. At the early stage the universal ancestor had "High Lateral Gene Transfer and Mutation Rates (hence high evolutionary temperature)" among the cells. So no individual cell posses its own history as new innovative genes could be easily shared and rapidly exchanged among the cells resulting in an enormous evolutionary potential. These cells evolved and survived as a single unit.

As the lateral gene transfer and mutation rates decreased, Subsystems are formed. Translation's components were among the first to be made and utilized. This was suggested from the fact that translation is a complex RNA-based mechanism. The translation mechanism was by far simpler than the present one. The translation machineries were limited in capability to function accurately at first so the proteins produced were not well capable in performing metabolic functions. By the lateral gene transfer, new translation components would be made and improved in other cells. New generation of proteins would be created with slight changes that refined their functions. This process was repeated iteratively to make the translation accuracy reached that level of modern cells.

Transcription had also formed at an early stage with a simple mechanism although there is no evidence indicating that it formed before or after translation. Due to the high mutation rate, the genes had to be small (mini-chromosomes) and each was present in multiple copies to stand a chance of getting replicated. Multiplicity of the chromosome ensured functionality when one or more copies of a gene were knocked out. Genes were also mobile so that the lateral gene transfer occurred well.

By the time that many subsystems formed, more complex structures emerged. The cells became more integrated and organized as well as being more resistant to the lateral gene transfer. Then a later stage the communal ancestor diverted into three domains as they could no longer freely communicate with one another. Each still behaved to some extent as a group of cooperative communal cells but in a much more restricted sense. These domains then ultimately developed into the ancestors of the three organismal domains (Eukarya, Bacteria and Archaea).

3. Conclusion

According to the Genetic Annealing Model of the universal ancestor, the phylogenetic tree our life on earth started from "progenotes" as loosely knitted group of primitive cells that evolved and survived as a single entity via exchanging of genes and metabolic materials. Through high lateral gene transfer and mutation rates then innovative genes could be developed and exchanged among the communal ancestor to produce complex machineries to help them evolve. As more complex subsystems were created, the universal ancestor became separated into three domains.

4. References

[1] Woese, C., The Universal Ancestor, *Proc. Natl. Acad. Sci.* **95**, 6854-6859 (1998).
[2] Wade, N., Tree of Life turns out to have Complex Roots, *The New York Times* April 14 (1998).