Review of: "Evidence for the Early Origin of Genes Leading to the Development of Biogeochemical Homeostasis at Planetary Scale"

Bernard Michaux

Potential competing interests: No potential competing interests to declare.

Phylogenetic Evidence for the Early Origin of the Homeostatic Influence of the Biota on Planetary-Scale Geophysical Processes

Mark Leggett, David A. Ball

The purpose of this paper is to establish when and how the earliest version of Gaia became operational based on empirical evidence provided by reconstructed genomes of early bacterial/archaea life and fossil evidence. The authors identify two core attributes associated with biological and earth-systems integration, namely some form of control system and interaction between elements. They provide examples purporting to show early life exhibiting aspects of these core attributes at varying scales.

My overall impression was that earlier versions of the paper lacked focus and that the authors didn't do justice to what is an interesting approach. This latest version is a considerable improvement.

I find it strange that there no reference by Lynn Margulis in a paper about Gaia. Margulis' contribution to Gaia theory is fundamental and should be acknowledged. In a wider social context, female participation in the sciences needs to be encouraged, and recognising the contribution of female scientists is vital as they have all too often been written out of history.

I think there is still a structural problem with the paper, which could easily easily remedied. As written it still reads to me in places like a series of bullet points. The end result is, to quote an apposite idiom, a concentration on the trees at the expense of seeing the wood. I think there is still potential to connect the individual ideas/data that would improve the paper's flow.

I have some thoughts concerning the central idea of Gaia. I think this is exemplified by the authors' discussion of Dawkins' criticism of Gaia based on selectionist arguments – Gaia *couldn't* have evolved because there's nothing to select between. This is a pretty ludicrous argument even for a Darwinian fundamentalist like Dawkins. Despite the fact that a global control system *cannot* exist for theoretical reasons, our atmosphere *has* been maintained far from chemical equilibrium for possibly 2.3 billion years by the action of organisms. The authors get themselves into a bit of tangle with their argument that planetary-wide control is contingent rather than a core attribute with their rather strained and unconvincing example of aircraft. While aspects of geochemical control may be localised in space, such control must be

able to operate wherever conditions allow and therefore can be regarded as planetary or even have a planetary-wide effect (localised iron enrichment of oceans as an example?). In short, I have no problem with the necessity of planetary-wide control systems and regard selectionist arguments as a red herring. The atmospheric example leads me to my second observation that the 'best of all possible worlds' result of the action of control systems simply isn't true. The initial production of oxygen as a waste product of cyanobacteria photosynthesis was a complete disaster for the dominant life forms. What it did do was to alter conditions that allowed for the eventual evolution of multicellular eukaryotes and consigned the anaerobes to marginal environments. To my mind, the Gaia phenomenon is an emergent property of life's interaction with the abiotic environment and of course this has to result in some form of regulation because life and Earth become coupled, so I'm sure the authors are correct to suggest Gaia started as soon as life evolved and was brought about by the necessity of organisms to maintain conditions conducive to their continued existence. Otherwise, I wouldn't be here writing this now. I'd like to see another example to illustrate control systems at a planetary scale rather than the forest example, as I don't see this as particularly relevant to the world at 3.8 Ga. Perhaps link the processes demonstrated by forests/trees to microbial processes?

Bernard Michaux

Kaukapakapa