# Martian life: stuck somewhere between inevitable biochemistry and quirky biology

*Charles H Lineweaver*

School of Physics
University of New South Wales

Australian Centre for Astrobiology
Sydney NSW

E-mail: charley@bat.phys.unsw.edu.au

If traces of life are found on Mars, the question that needs to be asked is: How independent is this life from life on Earth? A paradigm shift is needed from "Was there a second genesis?" to "How much of one was there?" This abandonment of a picture in black and white to a more nuanced grey is based on the idea that the boundary between life and non-life was not sharp and that the origin of life was an extended process of molecular tinkering.

Evidence for the idea that the origin of life was a long continuous process comes from the long list of transitions required for molecules to become microbes. This starts with the chemistry of molecular clouds and star forming regions and is followed by the formation and fractionation of protoplanetary accretion disks near circumstellar habitable zones and then by the deposition of water and volatile-rich and carbon-rich material of carbonaceous chondrites during the epoch of heavy bombardment (4.5 to 3.8 billion years ago). We have the molecular evolution of a diverse range of organic molecules: amino acids, sugars, nucleotide bases and alcohol. These monomers are so abundant in the universe that we expect that their synthesis took place on or near any terrestrial planet in the universe [1,2].

The formation of closed lipid bilayers to produce spheroidal membrane-bounded protobionts was the beginning of cellular life and follows directly from the physical chemistry of a class of amphiphilic molecules found in carbonaceous chondrites [3]. The transmembrane potential was then exploited as a source of energy. Dehydration condensation can be invoked to form polypeptides, to link sugars to nucleotide bases and also to store the chemical energy in the conversion between ADP and ATP. Prebiotic chemical selection based on an ability to form self-organising chemical systems probably resulted in the transition from racemic mixtures of amino acids and sugars to homochirality, and resulted in primitive porphyrins, fermentation and the primitive photosynthesis required for the transition from heterotroph to autotroph. With the development of a reproducible

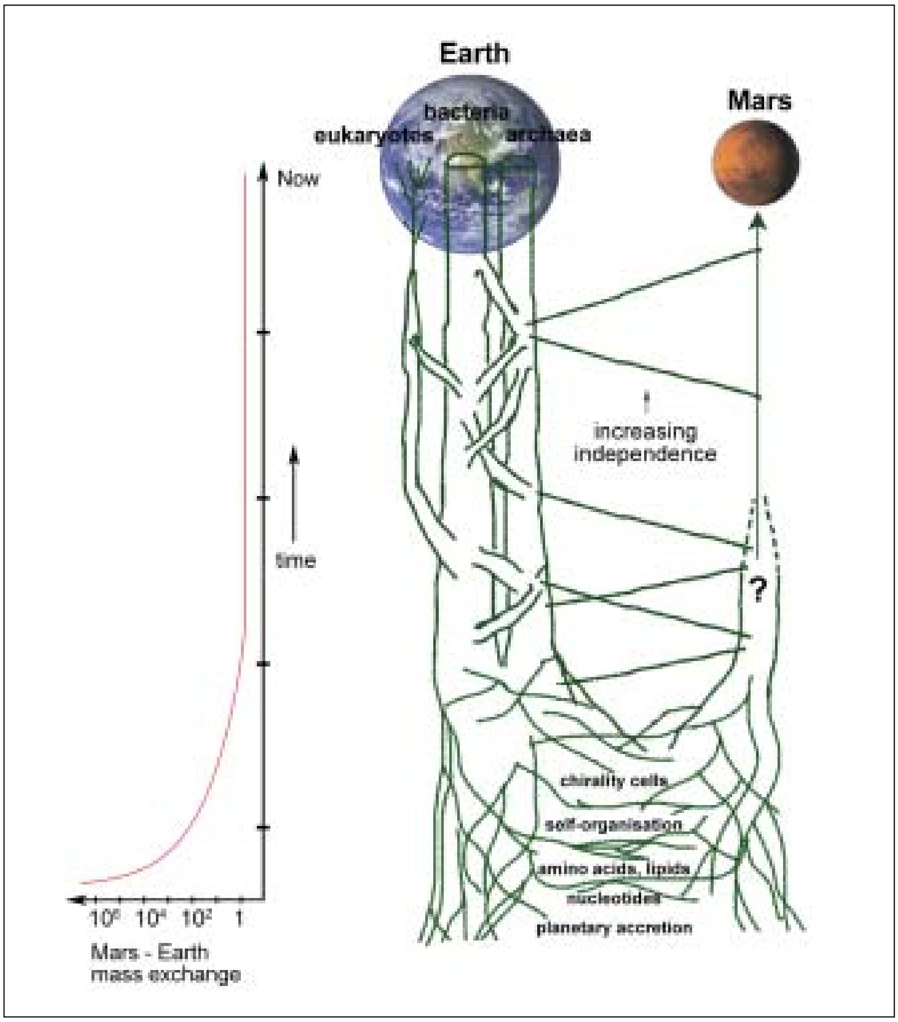


Figure 1. The divergence of Earth and Mars.
As we look into the past, the closer we get to the origin of the Earth and the origin of life on Earth, the less-independence we have of what was happening on Mars. Mars and Earth have a common ancestor: the inner Solar System. They emerged next to each other out of the same protoplanetary disk, with a large, ever-decreasing exchange of material between them during the formative period when life evolved, 4.5 to 3.8 billion years ago (plot on left). Only when the exchange rate subsided did some degree of independent evolution become possible. The stage in the origin of life at which the two planets became independent is the important question to be answered.

macromolecule, life evolved from a pre-genetic form to a genetic form using a genetic code. Then extensive lateral gene transfer (or the "annealing" of Woese [4]) subsided to form identifiable strains of bacteria and archaea.

In this sketch of the origin of life (Figure 1), an implicit assumption is the physical determinism and inevitability of the first steps, followed by progressively less determinism and more contingency as life's idiosyncracies emerge. For example, the formation of atoms everywhere in the universe is inevitable given the expanding cooling universe. The formation of heavy elements by stellar processes and the approximate relative abundances of these elements is inevitable given nuclear binding energies. The formation of roughly terrestrial rocky planets near the habitable zones of stars is probably inevitable for a wide range of stellar metallicities [5]. As we get closer to the origin of life, things may be less inevitable. Biochemical pathways become more complicated, auto-catalytic, self-organised and self-referential.

Physics and chemistry are deterministic sciences. If you study them here on Earth, you will be qualified to practise on the planets orbiting Proxima Centauri. Biologists can make no such claims. Rules for the development of proto-life anywhere in the universe are just the laws of physical chemistry constrained by the terrestrial planet boundary conditions. Based on this idea, Weber & Miller [6] wrote: *"If life were to arise on another planet, we would expect that... 75% of the amino acids would be the same as on the earth."* However, after the introduction of genetic information processing, new more self-referential rules apply.

Evidence for increased quirkiness in metazoan evolution comes from the sexual selection of extravagant colouration of face and genital regions. Features that have nothing to do with adaptation to a physical environment (peacock's tail) are selected as adaptations to the quirky behaviour of big-brained sex partners, enemies and allies. The complex feedback loops of ecosystems dominate the simple exigencies of chemistry and physics.

This transition from inevitable physics and biochemistry to the quirks of history and biological evolution [7] has special relevance for evaluating whatever signs of life we find on Mars (see Conway Morris [8] for a dissenting opinion on this progression from the deterministic to the quirky).

What, if anything, does "a second genesis on Mars" mean? What could we conclude from the discovery of a fossil on Mars? *"If the biochemistry made clear that Martian life derived from a separate and independent origin, it would surely suggest that the universe is teeming with the stuff"* [9]. Finding evidence for a second genesis on Mars would be strong evidence in favour of the idea that life is common in the universe [10].

With such evidence, we might be justified to call life a convergent feature of molecular evolution or a cosmic imperative [11]. However, the strength of this evidence for convergence on life depends on the degree of independence of Martian and terrestrial evolution. You cannot have convergence unless you first have divergence. The 'independent' evolution of the eye dozens of times is often cited as an example of convergence, but the basic biochemistry and retinol in these 'independent' examples are the same and result from more than 3 billion years of shared ancestry.

It may be the case that there is no identifiable event called the origin of life anymore than there was an identifiable event called the origin of France. Looking for DNA as a shibboleth among the earliest traces of life on Earth or on Mars may be overestimating the past importance of something which is only currently a universal feature of life – analogous to looking for buried French passports to determine when France originated.

Are we related to the guy next door? Of course we are, that is not an interesting question. The question is how closely are we related? Are we related to trees? Yes, but a long time ago (about 2 Gyr to 2 billion years). Are we related to *E. coli*? Yes but even longer ago (about 3 billion years). Are we related to the organic material deposited on the Earth and Mars 4 billion years ago? Yes, in a way. The threads of relatedness can be twined from compositional similarity, not just genetics.

Determining the degree of independence is what we should focus on, not on the naive question of complete independence or complete dependence. Will whatever traces we find of life on Mars be related to life on Earth? Of course it will be. Mars and Earth are not independent. They are both terrestrial rocky planets orbiting the same star containing the same elements, illuminated by the same temperature black body with the same energy photons. The interesting question is how closely related they are. Where in the long process called the origin of life did the lives of Mars and of Earth start to diverge?

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