

The Origin of Life

Definitions

- Bacteria/Archaea.
- Viruses.
- DNA-RNA-Protein-Enzymes. [dilemma: protein \leftrightarrow energy / DNA]
[“how life started without proteins”]
- ATP (“game of tag”)
- H, C, O [H + CO₂ → combine + energy]

Problem with origin of life concepts

Primordial soup—previous ideas assume that all the basic components of biochemistry originated first and then waited around to eventually combine into a living system. But chemistry happens fast or not at all. Too long and the reactants dissipate. More likely to generate life in 10,000 years than in 10 billion years. To get started it needs external energy that can drive it and containment that can keep it concentrated.

ASIDE If life arose as soon as the Heavy Bombardment ended, then there was not enough time in the old “primordial soup” notion. Therefore the hypothesis of panspermia from Mars, which had a head start, carried to Earth by meteorites (proven to be possible). HOWEVER, the proposed evidence for life at 3.8 BYA is not valid. Life had 300 MY to get started. Therefore the hypothesis of panspermia from Mars is not necessary.

Previous biochemical explanations have failed. RNA doesn’t develop in water or in clay (another model).

The “RNA World” idea assumes that replicating RNA came *before* metabolism— but RNA enzymes don’t replicate and evolve on their own (experiments)

Because replication is necessary for natural selection. In that view, origin of life is origin of replication. However, this is “like removing the engine from a car and expecting the controlling computer to do the driving” (Russell).

Solution: Deep Sea Alkaline Vents

Discovered in 2000. DESCRIBE. [Serpentinization...recycling the ocean...highly alkaline – high pH, flow of heat and hydrogen]

Matches hypothesis developed in 1988 (fossil vent, original conditions without oxygen) [ocean CO₂ acidified – like climate change]

HYPOTHESIS: *metabolism first* [not replication], from geochemistry with metal catalysts [not enzymes], a hydrogen source, and a thermal gradient.

Alkaline vents last 40,000 years whereas black smokers last 400 years and are way too hot. Deep sea location also protected from UV prior to creation of the ozone layer (John Baross).

Metabolism first

1. The most stable organic molecules are those of the central metabolic Krebs Cycle, therefore most likely to form first. [Food → energy] The mineral catalysts in the vent walls (Iron, nickel, sulphur) would have easily produced these. Can spin on it's own. [1st evidence for metabolism first; Krebs Cycle not invented by genes.]
2. Also produced the “feed stock” for the cycle [acetyl thioester (still used) → pyruvate].
3. Reverse Krebs Cycle is common in bacteria in vents ($\text{CO}_2 + \text{H} \rightarrow$ precursors). [Energy → structure/growth] At high concentration, it can also spin on its own. Reverse Krebs Cycle plus ATP can synthesize anything up to peptides and RNA, prior to natural selection.
4. BUT... Reverse Krebs Cycle needs energy from ATP. The mineral catalysts in the vent walls produced an alternative to ATP that sparked the Reverse Krebs Cycle. Today, alkaline vent microbes do this, using enzymes containing the same minerals. Thus Krebs and ATP both have “rocky roots.” [“smoking gun”]

Acetyl thioester + phosphate → acetyl phosphate, which functions like ATP in some bacteria today.

So vent automatically produced both kinds of metabolism, plus the feed stock, plus energy.

Now what about replication...?

5. Vents produced nucleotides that accumulated to extreme levels, condensing to become small RNAs and silting up the pores. IMPORTANCE of concentrated and replenished [other models don't address].
6. The vents then replicated RNA (natural PCR from thermal cycling) [amazing “coincidence” which introduces natural selection].
7. The genetic code itself shows its origin out of the Krebs Cycle (amino acid precursors). [2nd metabolism first.]

8. The unit of natural selection was the replicating small RNAs *together* with the metabolizing “rock-cell.”
9. DNA was recruited to allow complexity, and to unite a cooperating population of ***virus-like*** RNAs [c.f. retrovirus reverse transcriptase]. Also selection for independent coherence by leaving the rock mixture.

What about becoming free living cells...?

10. Gaining a membrane and becoming free living BIG PROBLEM:
 - ATP no net gain. Only ten dollar bills, can't make change.
 - Solution is proton gradient, “reservoir/turbine” [all life uses this] – why this weird way?
 - These vents make a natural proton gradient. [“smoking gun”] [using that early on]
11. To harness the proton gradient requires DNA, so DNA genes must have evolved prior to leaving the rock.

Experiments

- (1) Cambridge 2014 recreated vent conditions: got metabolism & nucleic.
- (2) Lane's reactor 2014– if semiconductor can make formaldehyde, you're over the hump – it does, but small amount – is it a breakthrough?

Implications of the new paradigm

The origin of life in the universe starts as geology, develops as geochemistry, and creates biochemistry and viruses at the same time as it creates life.

The Last Universal Common Ancestor happened before becoming free-living. **Two origins** from the same place.

(a) these two ancestral domains acquired cell membranes and cell walls in a completely different way, and different chemi-osmotic coupling.

(B) Mechanism for DNA replication originated in a totally different way in Bacteria and Archaea, probably as a result of (a)

Retroviruses are our ancestors and ongoing partners in evolution (most of the human genome is jumping genes ultimately originating as retroviruses). They should be recognized as “alive.”

IF TIME: **Introns** mix and match makes 3X number of genes. Originated as a defense against virus invasion of the DNA – introns are spliced out using molecular scissors taken

from the jumping gene viruses themselves. Then nucleus membrane barrier was needed to separate the two stages of splicing and translating into proteins. So viruses were primary cause of all animal and plant life.

All Earthlike planets will quickly originate life. Even moons like Europa.

IF TIME Interstellar free-floating Earth-size Europa-type planets, with internal radioactive heat and an ocean covered by deep ice, are as numerous as the stars. Even if they have intelligent animal life we'll never see them or be able to communicate with them.

Proposed “Weird Life” is highly unlikely. Even life on Europa would have originated in the same kind of alkaline vents and would therefore not be “weird life.”

Bad news: due to rare flukes needed to produce animal life, alien animals probably don't exist in our galaxy at this time.

PROBLEM Eukaryote ancestor was Archaea with symbiotic Bacteria as mitochondria. **BUT** -- Phagocytosis must have come afterwards, because it's energetically impossible without mitochondria. Thus a rare “fateful encounter” was needed to get endosymbiosis without phagocytosis. That, plus the fluke of photosynthesis for oxygen, makes alien animals much less likely.

(IF TIME) REBUTTAL by de Duve 2005 – because endosymbiosis happened a second time with chloroplasts, he suggests a range of such events happened during a “selective bottleneck” optimized by natural selection –thus not a lucky accident, therefore animal aliens highly probable.

GOOD NEWS THIS WEEK! New Scientist – “blebs” **inside-out origin** (archaea do this; nucleus/ER show archaeal cell wall molecules). ALIEN ANIMALS MAY BE COMMON.

Alien animals are likely to be similar to us. Only ribose works for creating genetic material (Benner), so alien life is likely based on DNA, with the same DNA code (Lane Chapter 2). Animal life requires oxygen (Lane Chapter 3), so aliens will breathe oxygen and probably even have mitochondria (Lane).

For discussion

- Missing the boat, pet theory bias examples: 2014 Woods Hole black smokers tested methanethiol as precursor.
- 40 billion earthlike planets in the galaxy.
- Pores – 1 to 1,000 microns. Bacteria 1 to 100 microns. Both mainly around 10 microns.
- Thimbleful of seawater includes 10 million viruses.