The Origin of Life:
Chance, Necessity or Design?

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Notes for Faraday Seminar,
April 23, 2024 1:00 pm - 2:00 pm

1 Preamble

1.1 My Agenda

1. Evangelism
2. Interest
3. Persuasion

1.2 Overlap Between Science and Public Square

Both scientists and culture warriors are interested in the question of:
chance, necessity, or design.
See Dembski & Tour (2023, `https://idthefuture.com/1824/`), Axe (2017), Meyer (2009).

2 Chance, Necessity and Design

> “ But now if you had two sorts of things, the one of which presents no clue as to what it is for, and the other is obviously for some useful purpose—which would you judge to be the result of chance, which of design?
>
> XENOPHON'S SOCRATES,
> MEMORABILIA, 4.2-7 (TR. H. G. DAKYNS)

2.1 History of Chance, Necessity and Design

1. Ancient Thinkers
   i) Xenophon's Socrates on Chance vs Design (Memorabilia)
   ii) Aristotle on Chance vs Necessity (Physics II, 4-6)
   iii) Philo (On the Creation)

2. Medieval Thinkers
   i) Hallevi & Maimonides (Wolfson, 1941)
   ii) Thomas Aquinas (Feser, 2019)

3. Modern Thinkers
   i) Jacques Monod (1974) on Chance & Necessity. See also (de Duve, 2007).
   ii) Stephen Meyer, inference to the best explanation (Meyer, 1991, 2009)

2.2 The Exclusiveness of Chance, Necessity and Design

1. The Briggs–Rauscher oscillating reaction
   i) Demonstration of the Reaction: I^{+5} to I^{+0} to I^{-1}
      a) Bulk rates can be used with time-variable rate-constants to indicate oscillating behavior, but with no explanation as to why.
      b) Full description of this process requires a network containing at least 30 different reactions that include an *autocatalytic cycle* (Epstein and Pojman, 1998).
   ii) **Necessity:** "Nature is everywhere and always the same" (Spinoza). If the initial conditions are the same, the reaction will proceed the same.
   iii) **Chance:**
      a) *Macroscopic:* The initial conditions are never identical, and subtle differences from one run to the other mean there is a chance component.
      b) *Microscopic:* Chance collisions between different molecules, atoms and ions result in the macroscopic process: "order from disorder" (Schrödinger, 1944).
   iv) **Design:**
      a) *Macroscopic:* Chemicals, beakers, spatulas, etc., were intelligently designed. Experiment was intelligently designed; not likely to occur spontaneously.
      b) *Microscopic:* Design intuition is even stronger when it comes to the sequence of reactions, which is far more carefully balanced and orchestrated than any of the actions of the experimentalist or other designers. This appears like a "signature of the divine" (Marilynne Robinson, Genesis). What do we do with our intuition?

2. Necessity of the Philosophers (Kripke, 1980) vs. Necessity of the Scientists
    i) Logical Necessity
    ii) Metaphysical Necessity
    iii) Nomological Necessity
3. Varieties of Chance (Alexander, 2018, 2020, 2022)
    i) Epistemic, Ontological and Metaphysical Chance
    ii) Chance and Randomness
    iii) Chance and Stability
4. Design and Varieties of Divine Activity
    i) Processes explained by chance and necessity may also require explanation of design, regardless of the activity of the designer God, going from deism to occasionalism. See Kojonen (2021).
    ii) Occasionalism as a toy model:
        a) Occasionalism is a respected position with a long history, especially in Islam and Reformed Protestantism (Fakhry, 2013; Crisp, 2016; Malik, 2021).
        b) Diffuses ID-related concerns.
        c) *Any* model that has God acting in the lab the same was as in the wild will do the same.
        d) This is *not* the same as methodological naturalism (Baker, 2013).
        e) Trivially exhaustive.

2.3 The Exhaustiveness of Chance, Necessity and Design

1. Given occasionalism, design is trivially exhaustive.
    i) Even here, we may understand the regularity of divine activity in terms of chance and necessity; are these now exhaustive?
    ii) Other models of divine activity distinguish primary and secondary causes. Here, some events may not be directly caused by God.
2. It seems the *non-mechanical* nature of life (Nicholson, 2019) and its convergent evolution (Louis, 2016; Kojonen, 2021), admits to purpose. Purpose-language is not easily folded into either chance or necessity.
    i) Teleology has been popular among certain philosophical schools (Feser, 2019; De Haan, 2017).
    ii) A teleological/teleonomical approach is gathering interest among origins of life researchers and biologists (Corning et al., 2023).
    iii) Cosmological fine-tuning (Lewis and Barnes, 2016) may also be explained in ways that may require some other category.

3 Origins of Life: A Scenario

3.1 Some Context: What Does Life Need?

1. Overview of origins of life. Two very useful resources are Eigen (2013) and Fahrenbach and Cleaves (2024).

2. Some **assumptions**:
   i) Life is made of chemistry (even though life is not chemistry; see C.S. Lewis).
   ii) The origins of life is at its core a synthetic chemistry problem.
   iii) Origins of life involves many other fields.
   iv) This work requires an interdisciplinary approach, with great epistemic humility (Preiner et al., 2020; Lane and Xavier, 2024).
   v) Life originated without the involvement or interference of a finite intelligent agent (Rimmer and White, 2024).
   vi) Life originated on Earth.

3. Four things life needs: what life as we know it has.
   i) Informational polymer: deoxyribonucleotides, ribonucleotides.
   ii) Kinetic control: proteins, ribozymes.
   iii) Containment: phospholipid membranes.
   iv) Metabolism: CTA Cycle.
   v) **LOTS of scenarios center around the argument: which of these happened first?**
   vi) Life as we know it has all these things mixed up – chicken-and-egg problems.

3.2 The Scenario

Text in bold refers to **coincident events or conditions** where **the process is aimed in some way at the same outcome as that sought by the prebiotic chemist.**

1. Earth formed roughly 4.5 billion years ago (Zahnle et al., 2010).
   i) Moon-forming impact took place roughly 4.4 billion years ago. Even if Earth's surface were habitable before this event, the moon-forming impact would have been completely sterilizing, and resetting (Zahnle et al., 2010).
   ii) Subsequent volcanic atmosphere is warm and redox-neutral: CO_2, N_2, CO, H_2O (Zahnle et al., 2010).

2. A subsequent giant impact, much smaller than the moon-forming impact, evaporated most of the ocean (Genda et al., 2017). **Only probable within the first couple hundred million years from Earth's formation.**

   i) The iron reacted with the water to reduce the atmosphere: H_2, N_2, CH_4, CO, NH_3, H_2O. **This atmosphere would have survived for roughly a million years** (Genda et al., 2017; Zahnle et al., 2020).
   ii) Subsequent photochemistry formed HCN, HC_3N, and many other compounds. High chemical diversity, high chemical complexity (Wogan et al., 2023). Counter-intuitively, this is very bad for prebiotic chemistry (Rimmer and White, 2024).
   iii) Rainout and tarrification (Wogan et al., 2023): more reactions on the surface and in water, even worse for prebiotic chemistry.

3. Processing of the tar in the Earth's crust.
   i) Tar is incorporated into the crust from subduction, sinking, or subsequent impact (Rimmer and Shorttle, 2024).
   ii) Tar is heated by volcanism **at much higher temperatures than magma reaches on Earth today** (Rimmer and Shorttle, 2024).
   iii) The vast majority of the carbon in the tar is converted into graphite, leaving behind molecular species that are **either effectively inert**: H_2, CO, H_2O, CH_4, CO_2, N_2; or are **the same species chosen by organic chemists for prebiotic synthetic reactions:** HCN, HC_3N, CH_3NC, HNC and H_2S (Rimmer and Shorttle, 2024). Much lower chemical diversity, and even lower chemical complexity.
   iv) Bubbles through surface hydrothermal vent (Rimmer and Shorttle, 2019, 2024).
   v) Surface hydrothermal vents **fortuitously meet many of the requirements for a diverse set of prebiotic chemical reactions (Barge and Price, 2022; Rimmer and Shorttle, 2024; Matreux et al., 2024).**

4. Ultraviolet photochemistry with cyanide and other nitriles. For a comprehensive review, see (Green et al., 2021). This involves light from stars **like the sun**, and in environments **without much atmospheric oxygen**.
   i) Surface hydrothermal vents will bubble up this reducing gas along with some more oxidizing gas, such as SO_2 (Rimmer and Shorttle, 2019).
   ii) The SO_2 will react with water to form sulfite, an anion. **Ultraviolet light of solar intensity will efficiently** detach an electron from the sulfite, which can go on to reduce HCN twice. Subsequent reactions result in formaldehyde. The same reaction can occur with formaldehyde and HCN to form simple sugars (Ritson and Sutherland, 2012; Xu et al., 2018).
   iii) Sugars will react with NH_2CN to form several ribo-aminooxazolines, along with other imidazoles and oxazoles (Patel et al., 2015).
   iv) The ribo-aminooxazolines can crystalize and will **naturally sort themselves**, not only by type but by chirality, preserving almost exclusively a single chirality of ribo-aminooxazoline (Ozturk et al., 2023).
   v) The D-ribo-aminooxazolines react with cyanoacytelene to form D-ribonucleotides (Powner et al., 2009; Patel et al., 2015).

vi) Many of the byproducts and side products of the reaction will, **in certain circumstances**, form half a dozen amino acids and phospholipids (Patel et al., 2015)

vii) Other side products, such as the imidazoles, **will fortuitously react** with CH_3NC, attaching themselves to amino acids, nucleotides and phospholipids, activating them, and joining them together in the same way enzymes join these molecules together in living systems (Mariani et al., 2018; Liu et al., 2020).

viii) These activating agents will also join nucleotides to amino acids, showing some **fortuitous patterns** that resemble the second genetic code in life as we know it (Su et al., 2023). The selected amino acids also tend to have the opposite handedness of the nucleotide, so R-nucleotides select L-amino acids (Ozturk et al., 2023b).

ix) The **aftermath of the giant impact** will have cooled the Earth's surface (Kadoya et al., 2020), freezing and raising the pH at the edges of the hydrothermal vents, which helps favor the kinetics for productive chemistry (Todd et al., 2019; Rimmer et al., 2021; Todd et al., 2022).

x) It also **just happens that** the nucleotides that are produced by photochemistry, also the ones used by life, are the nucleotides that are most resistant to ultraviolet degradation, and in these chemical environments, can even self-repair (Kufner et al., 2024).

5. Subsequent steps - Emergent behavior in chemical systems.

   i) Many of these chemical environments may begin to exhibit certain self-organizing behaviors. Prebiotic chemical networks like the one invoked in this scenario already contain within themselves autocatalytic cycles (Robinson et al., 2022; Ianeselli et al., 2023), and can meet the general evolution criteron for stable non-equilibrium systems (Glansdorff and Prigogine, 1971; Pascal et al., 2013). Behaviors, in other words, **similar to but also transcending** the behavior of the Briggs–Rauscher oscillating reaction.

   ii) The exhibition of these behaviors may be highly contingent, **implying that life is possibly rare or even unique to Earth** (Rimmer, 2023).

   iii) Some of these systems seem to exhibit a natural "do-nothing chemistry" (Fukuoka, 2009; Rimmer and White, 2024), that can match all the assumptions and criteria mentioned above.

4 Concluding Remarks

This may well not be the only scenario that exhibits this behavior, or even the most likely scenario. I hypothesize that the teleological character of many of the sequences in this scenario is a sign of being on the right track, and that future signatures of teleology will indicate fruitful new research avenues. I plan to take this approach in my own research for the next few years, and will find out how successful this approach turns out to be.

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