Birth of the First Replicator

Abstract

This essay reframes the birth of the first replicator, the pivotal transition in abiogenesis, as a Multi-Agent System (MAS) phenomenon. Using the minimalist chain `energy` → `blobs` → `stability` → `replication` → `selection`, we focus tightly on how a non-living ensemble of simple agents, driven by resource gradients and noise, can cross the threshold into self-copying organization. Replication is treated not as a miracle step but as an emergent protocol arising from local rules, stability biases, and chance encounters.

Core Question

How can inert building blocks, buffeted by energy and noise, spontaneously configure into a structure that (i) persists and (ii) makes copies of itself? The MAS view replaces an exhaustive chemical catalog with a small set of agent rules and environmental fields that allow such a configuration to appear with non-zero probability and then spread.

DNA and RNA (the winning replicators of Earth) in one minute

DNA is life's long-term memory: a **double helix** with base-pairing (A–T, C–G) that enables **templated copying**. It's **chemically stable**, excellent for accurate storage, but typically needs **enzymatic helpers** to replicate.

RNA is usually **single-stranded** (A, U, C, G), can **fold into shapes**, and some RNAs are **ribozymes** (catalysts). Evidence for an **RNA-first** stage: (1) the **ribosome's** catalytic core is RNA; (2) cells make **DNA building blocks from RNA ones**; (3) lab RNAs can **catalyze ligation/polymerization**, hinting at primitive self-copying. Thus, **RNA likely preceded DNA** because it can both **store information** and **do chemistry**; **DNA** appears later as a **more stable archive** once enzymatic machinery evolves.

Origin-of-life mental model

A bare-bones sketch of how simple stuff, pushed by **energy** and **chance** across a vast expanse of time, climbs toward life.

Steps

- Over time, **very simple building blocks** fill the void.
- On their own they can't interact effectively—we need **excess energy**.
- Introducing **energy** (e.g., **UV light** or **volcanic heat**) gives a small chance that they **combine**.
- They combine into **blobs**. These blobs may **split** again after some time or **persist**, depending on their properties.
- We need these blobs to become increasingly **stable** (**"law of stability"**).
- Once more stable, blobs can **interact** with one another and, by the **law of stability**, form **systems more stable than the sum of their parts**—entirely by chance.
- Also by chance, some blobs may configure into a very **stable form** that not only exists but also **attracts other building blocks** and then **releases them**, creating an **exact copy** of themselves.
- The **first replicator** is born.
- In theory, this replicator would **fill the entire void**, but in reality **errors** are introduced during replication.
- We call these errors **mutations**.
- **Mutations** can produce **better strategies** for replicating or surviving, because they **change which building blocks are attracted and replicated**.
- Due to mutations, some replicators develop **offensive traits** to attack others, while some develop **defensive shells** to protect against a harsh environment.

Replication changes everything. The first replicator didn't need to be smart, it only needed to be lucky. It existed in a sea of random blobs, but now there was a new rule in town: **THE COPIES SPREAD**. Every copy took up space and resources, leaving less for everything else. But copies were not perfect. Each replication came with small **errors**, small changes in the pattern. Most errors made the new copy worse, but some made it **better**—more stable, more efficient, or faster at making more of itself.

Keep the model simple:
`energy` → `blobs` → `stability` → `replication` → `selection`.
Everything else is just **detail**.

MAS reframing of the five-step chain

- **Energy fields:**
  - UV, geothermal, or redox gradients become spatial – temporal fields that enable or disable reactions locally.
- **Blobs, or our Agents:**

    - Vesicles, micelles, mineral-templated complexes, and polymers are agents with states (size, permeability, binding affinities) and simple policies (absorb, bind, merge, split, decay).
- **Stability (local utility bias):**
    - Structures with better enclosure or lower exposure survive longer. Stability acts like an implicit utility that biases which states persist.
- **Replication:**
    - Certain configurations enact an assembly routine, they attract ingredients and re-instantiate their own pattern.
- **Selection and population dynamics:**
    - Copying with noise produces lineages; differing replication and decay rates alter the population composition over time.

Minimal formalization aimed at replicator birth

What makes replication emerge?

1. **Energetic windows:** Too little energy yields no assembly, too much breaks bonds. There is a Goldilocks zone.
2. **Stability bias:** Longer-lived agents attempt more templating steps, increasing chances of discovering.
3. **Spatial concentration:** Local crowding increases encounter rates, making templating routines more likely to complete.
4. **Noise as search:** Mutations explore parameter space; occasionally, a template-competent configuration appears.

Error threshold and fidelity

Replication must balance innovation and integrity. If mutation noise exceeds an error threshold, the lineage fails to preserve the template (error catastrophe). Below threshold, the template persists and can fixate.

Positioning in Intelligent Systems

- **Decentralized emergence:** Replication appears without a central controller via local rules—canonical MAS emergence.
- **Proto-adaptation:** Selection over noisy copies is learning without learners; a population-level credit assignment.

- **Coordination and competition:** Protective shells and parasites are roles in a multi-agent game under resource constraints.

Conclusion

In the MAS framing, the birth of the first replicator is the moment a local interaction routine becomes self-amplifying under the right energy and stability conditions. With minimal rules `energy` → `blobs` → `stability` → `replication` → `selection` a non-living system steps over a threshold into copy-preserving dynamics, enabling evolution and, eventually, life. This is a crisp, simulation-ready account of how intelligence-like organization can emerge from dumb parts plus time.