

Life as a Filtered Outcome: Filtered Configuration Framework

Version 2 (Extended)

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Abstract

Abiogenesis is commonly framed as a problem of probabilistic generation under early Earth conditions. This paper argues that such framing is incomplete. We introduce the *Filtered Configuration Framework* (FCF), in which the observable biochemical landscape is interpreted as the result of successive filtering processes acting on a broader configuration space.

The framework is grounded in two principles: (1) environmental filtering, according to which observable structures are those compatible with specific conditions, and (2) generation–survival decoupling, according to which the conditions required for formation may differ substantially from those required for persistence. In addition, configurations are treated not as isolated objects, but as elements of environment-dependent transformation processes.

Within this formulation, observability is further constrained by epistemic conditions (Coherent Observational Epistemology), such that only configurations compatible with both environmental and observational interfaces can be detected.

We derive formal consequences showing that observability does not imply local generability, and that the absence of configurations in empirical data does not constitute evidence of their impossibility. Moreover, the framework implies that the constructive synthesis of specific configurations under controlled conditions is not, in general, invariant with respect to environment-dependent transformation processes.

Instead, the observable domain is a biased subset shaped by generation, transformation, survival, and observability constraints.

This reframes abiogenesis from a problem of local emergence of specific structures to a problem of transformation, filtering, and accessibility across environments, independent of whether the origin of configurations is local or external.

Keywords: abiogenesis; origin of life; environmental filtering; generation–survival decoupling; observability; Coherent Observational Epistemology; Filtered Configuration Framework; transformation processes; epistemic bias; laboratory reconstruction

Contents

1	Introduction	2
2	Three-Stage Filtering Structure	3
3	Environmental Filtering	3
4	Generation–Survival Decoupling	4
5	Implications for Abiogenesis	6
6	Epistemic Misplacement in Abiogenesis Reasoning	8
7	Observability as a Constraint (COE Perspective)	11
8	Panspermia as a Natural Consequence of FCF	12
9	Extended Epistemic Filtering	13
10	Extended Filtering Structure	14
11	Conclusion	15
A	Probabilistic Formulation of Environmental Filtering	17
B	Examples Beyond Biology	23
C	Medium-Dependent Transformation and Productive Decay	24

1 Introduction

The origin of life is commonly framed as a problem of spontaneous emergence under early Earth conditions. Standard approaches attempt to estimate the probability of forming complex biomolecular structures from simpler precursors within a given environment, often treating the observable biochemical landscape as representative of the underlying generative space.

This paper argues that such framing is incomplete.

We introduce the *Filtered Configuration Framework* (FCF), in which the observable set of structures is understood not as a direct reflection of generative possibilities, but as the result of successive filtering processes acting on a much larger configuration space. These processes include generation constraints, environment-dependent transformation, survival constraints, and observational (epistemic) constraints.

This perspective is consistent with Coherent Observational Epistemology (COE), which holds that all observations are produced through local interaction interfaces and are inherently constrained by the conditions of those interfaces [1]. Observability is therefore not a neutral window into reality, but a filtered projection determined by compatibility between the observer, the environment, and the configuration itself.

Within this framework, configurations are not treated as isolated objects, but as elements of environment-dependent transformation processes. As a consequence, the central assumption of many abiogenesis models—that the space of observable structures reflects the space of possible generation pathways—no longer holds.

Instead, the observable biochemical domain is interpreted as a restricted subset shaped by:

- generation constraints (what can be formed),
- transformation processes (how configurations evolve within an environment),
- survival constraints (what can persist),
- observability constraints (what can be detected).

The Filtered Configuration Framework formalizes this structure through explicit operators and probabilistic representations, and demonstrates that:

- observability does not imply local generability,
- absence of configurations does not imply impossibility,
- and the current form of life reflects environmental filtering of transformation processes rather than the full space of possible biochemical realizations.

This reframes the problem of abiogenesis: from the question of how specific molecular structures were produced under particular conditions, to the more general question of how configurations are generated, transformed, filtered, and rendered observable across environments.

2 Three-Stage Filtering Structure

The Filtered Configuration Framework can be summarized as a sequence of filtering stages:

$$\mathcal{C} \xrightarrow{G_{E_g}} \mathcal{G}_{E_g} \xrightarrow{S_{E_s}} \mathcal{S}_{E_s} \xrightarrow{C_I} \mathcal{R}_{E_s, I}$$

Interpretation

- \mathcal{C} : space of possible configurations,
- \mathcal{G}_{E_g} : configurations generable under environment E_g ,
- \mathcal{S}_{E_s} : configurations survivable under environment E_s ,
- $\mathcal{R}_{E_s, I}$: configurations registered under survival conditions E_s and interface constraints I ,
- G_{E_g} : generation operator,
- S_{E_s} : survival operator,
- C_I : interface/coherence operator.

Thus, the empirically accessible domain is the result of successive filtering:

$$\text{possible} \rightarrow \text{generable} \rightarrow \text{survivable} \rightarrow \text{registered}$$

3 Environmental Filtering

We formalize the Environmental Filtering Principle as an axiom.

Axiom 1 (Environmental Filtering)

Let \mathcal{C} denote the space of all physically realizable configurations, and let E denote a specific environment characterized by a set of constraints (e.g., temperature, pressure, chemical composition, radiation).

Define a survival operator:

$$S_E : \mathcal{C} \rightarrow \{0, 1\}$$

such that

$$S_E(c) = \begin{cases} 1, & \text{if configuration } c \text{ remains stable under environment } E \\ 0, & \text{otherwise} \end{cases}$$

Then the set of observable configurations under environment E is given by:

$$\mathcal{O}_E = \{c \in \mathcal{C} \mid S_E(c) = 1\}$$

Interpretation

Observable structures are not representative of the full configuration space \mathcal{C} , but only of the subset \mathcal{O}_E that survives under the constraints imposed by E .

Remarks

- The operator S_E captures environmental selection as a filtering mechanism, not as an active or intentional process.
- In general, $|\mathcal{O}_E| \ll |\mathcal{C}|$, reflecting the asymmetry between generation and survival.
- Changes in environment $E \rightarrow E'$ induce a transformation of observable sets:

$$\mathcal{O}_E \neq \mathcal{O}_{E'}$$

Environments do not merely enable formation; they also eliminate unstable configurations. As a result, the set of observed structures is determined primarily by survival constraints rather than generative potential.

4 Generation–Survival Decoupling

We formalize the Generation–Survival Decoupling Principle as an axiom.

Axiom 2 (Generation–Survival Decoupling)

Let \mathcal{C} denote the space of all physically realizable configurations, and let E_g and E_s denote, respectively, an environment of generation and an environment of survival.

Define a generation operator:

$$G_{E_g} : \mathcal{C} \rightarrow \{0, 1\}$$

such that

$$G_{E_g}(c) = \begin{cases} 1, & \text{if configuration } c \text{ can be formed under environment } E_g \\ 0, & \text{otherwise} \end{cases}$$

Define a survival operator:

$$S_{E_s} : \mathcal{C} \rightarrow \{0, 1\}$$

such that

$$S_{E_s}(c) = \begin{cases} 1, & \text{if configuration } c \text{ remains stable under environment } E_s \\ 0, & \text{otherwise} \end{cases}$$

Then, in general,

$$G_{E_g}(c) \neq S_{E_s}(c)$$

for a given configuration $c \in \mathcal{C}$.

More specifically, there may exist configurations such that

$$\exists c \in \mathcal{C} : G_{E_g}(c) = 1 \wedge S_{E_s}(c) = 0$$

and also configurations such that

$$\exists c \in \mathcal{C} : G_{E_g}(c) = 0 \wedge S_{E_s}(c) = 1$$

Interpretation

The conditions required for the formation of a structure may differ significantly from the conditions under which it remains stable. Formation and persistence therefore belong to distinct environmental regimes and must not be conflated.

Remarks

- The first case,

$$G_{E_g}(c) = 1 \wedge S_{E_s}(c) = 0,$$

represents configurations that can be generated in one environment but do not survive in another.

- The second case,

$$G_{E_g}(c) = 0 \wedge S_{E_s}(c) = 1,$$

represents configurations that cannot be generated locally under a given environment, but could remain stable if introduced from elsewhere.

- Hence, the observable set under an environment E does not in general coincide with the generable set under the same environment.

A well-known analogy is diamond formation: diamonds require high-pressure environments to form, yet remain stable under standard surface conditions. This illustrates that formation and persistence operate under distinct regimes.

Extending this principle to prebiotic chemistry suggests that certain molecular configurations may have formed under conditions not present on early Earth, or under transient or localized conditions, and subsequently either stabilized or disappeared.

$$\mathcal{O}_{E_s} = \{c \in \mathcal{C} \mid S_{E_s}(c) = 1\}$$

while the generable set under E_g is

$$\mathcal{G}_{E_g} = \{c \in \mathcal{C} \mid G_{E_g}(c) = 1\}.$$

In general,

$$\mathcal{G}_{E_g} \neq \mathcal{O}_{E_s}.$$

5 Implications for Abiogenesis

We derive implications directly from Axiom 1 (Environmental Filtering) and Axiom 2 (Generation–Survival Decoupling).

Definitions

Let \mathcal{C} denote the space of physically realizable configurations.

For an environment E :

$$\mathcal{G}_E = \{c \in \mathcal{C} \mid G_E(c) = 1\}$$

is the set of configurations generable under E , and

$$\mathcal{O}_E = \{c \in \mathcal{C} \mid S_E(c) = 1\}$$

is the set of configurations observable under E (i.e., those that survive).

Theorem 1 (Non-local Generability)

Not every configuration observable under an environment E must be generable under the same environment.

$$\exists c \in \mathcal{C} : S_E(c) = 1 \wedge G_E(c) = 0$$

Proof.

From Axiom 2, there exist environments E_g and E_s such that

$$G_{E_g}(c) = 1 \wedge S_{E_s}(c) = 1$$

while

$$G_{E_s}(c) = 0.$$

Let $E = E_s$. Then

$$c \in \mathcal{O}_E \quad \text{but} \quad c \notin \mathcal{G}_E.$$

Hence, observability does not imply local generability. \square

Theorem 2 (External Transfer and Selective Survival)

Configurations generated under one environment may be transferred into another environment, where only a subset survives.

Formally, there exist E_g , E_s and a subset $\mathcal{T} \subset \mathcal{G}_{E_g}$ such that

$$\mathcal{O}_{E_s} \cap \mathcal{T} \subset \mathcal{T}.$$

Proof.

From Axiom 2, there exist configurations $c \in \mathcal{C}$ such that

$$G_{E_g}(c) = 1.$$

Under a different environment E_s , Axiom 1 defines survival via S_{E_s} . Therefore, only configurations satisfying

$$S_{E_s}(c) = 1$$

remain observable.

Thus, for any transferred set $\mathcal{T} \subset \mathcal{G}_{E_g}$, the observable subset is

$$\mathcal{O}_{E_s} \cap \mathcal{T},$$

which in general is a strict subset of \mathcal{T} due to environmental filtering. □

Corollary (Observational Bias)

$$\mathcal{O}_E \subseteq \mathcal{G}_E \cup \bigcup_{E' \neq E} \mathcal{G}_{E'}$$

The observable set under E may include configurations generated under different environments, while excluding many that are generable but not survivable.

Medium-Dependent Transformation

Standard arguments in abiogenesis frequently evaluate the plausibility of candidate molecules in terms of their intrinsic stability under isolated conditions (e.g., in aqueous solution). Within the Filtered Configuration Framework, such an approach is incomplete.

Configurations do not exist in isolation but as elements of an environment-dependent transformation process. Accordingly, the relevant object is not a configuration c alone, but the pair (c, E) , where E denotes the environment.

Instead of a binary survival criterion,

$$SE(c) \in \{0, 1\},$$

it is necessary to consider the transformation mapping induced by the environment:

$$T_E(c) = \{c'_1, c'_2, \dots\},$$

where $T_E(c)$ denotes the set of configurations produced from c under environment E .

Under this formulation, instability of a configuration does not imply its irrelevance. A configuration may fail to persist as an identifiable entity, yet still contribute systematically to the formation of other configurations.

We therefore distinguish between eliminative decay and productive decay. Let $L(c)$ denote a measure of structural connectivity or relational integration. A transformation is said to be

productive if

$$\mathbb{E}[L(c')] > L(c), \quad c' \in T_E(c).$$

In such cases, the decay of a configuration increases the structural integration of the resulting ensemble. Consequently, molecular instability at the level of isolated configurations does not entail a decrease in configurational complexity at the level of the medium.

This extends the interpretation of environmental filtering. The survival operator SE should not be understood solely as preservation of individual configurations, but more generally as persistence of transformation regimes compatible with the environment.

Implication. Objections to abiogenesis based solely on the instability of specific molecules (e.g., sugars in aqueous environments) are underdetermined. Within FCF, the relevant question is not whether a configuration persists in isolation, but whether its environment-dependent transformations contribute to configurations that remain accessible under survival and observability constraints.

Conclusion

The observable biochemical landscape does not reflect the full space of generable configurations, but only those that have survived environmental filtering.

Therefore, life as observed on Earth should be understood as a filtered outcome: a subset of configurations that remained stable under terrestrial conditions, regardless of whether their origin was local or external.

Moreover, this interpretation should not be restricted to the stability of isolated molecular configurations. Within realistic environments, configurations participate in transformation processes rather than existing as independent entities. Consequently, instability of a given configuration does not imply its irrelevance: it may contribute to the formation of other configurations that satisfy survival constraints.

Thus, environmental filtering operates not only through the preservation of stable configurations, but also through the selective retention of transformation pathways compatible with the environment. In this extended sense, what persists is not necessarily the configuration itself, but the transformation regime in which it participates.

This further reinforces the central claim of FCF: the observable domain is determined not by generative possibility alone, but by the combined effects of generation, transformation, survival, and observability constraints.

6 Epistemic Misplacement in Abiogenesis Reasoning

The preceding analysis establishes that observable biochemical structures are the result of filtering processes acting on a broader configuration space. However, a substantial portion of abiogenesis research relies on implicit epistemic assumptions that are incompatible with this framework.

In particular, modern biochemical knowledge is frequently projected onto prebiotic conditions, leading to systematic distortions in the formulation of the problem. Within the Filtered Configu-

ration Framework, such reasoning constitutes a class of epistemic misplacements.

(1) Temporal Epistemic Transfer Contemporary biochemical structures are treated as if they were the natural starting point of prebiotic processes. However, these structures are themselves the result of extensive environmental filtering and evolutionary stabilization.

Thus, projecting present-day configurations backward in time conflates outcomes with initial conditions. Within FCF, this corresponds to mistaking the observable set O_E for the generable set G_E , which is not valid in general.

(2) Retrospective Baseline Bias Molecules that appear fundamental in modern biology (e.g., specific sugars, nucleotides, or cofactors) are often assumed to be intrinsically privileged in prebiotic chemistry.

Within FCF, this assumption is unwarranted. Observed biochemical components are not selected for their generative simplicity, but for their compatibility with survival and observability constraints under current environmental conditions.

Therefore, what appears as “basic” or “foundational” may instead be a highly filtered endpoint rather than a primitive starting configuration.

(3) Target-Oriented Reconstruction Bias A central methodological assumption in abiogenesis research is that the problem consists in generating specific biomolecules under controlled conditions.

Within FCF, this assumption is structurally misplaced.

The framework implies that configurations do not arise as isolated targets, but as transient states within environment-dependent transformation regimes. The relevant object of analysis is therefore not a molecule c , but a transformation process T_E acting on a configuration space.

Laboratory protocols, however, invert this structure. They:

- define a target configuration in advance,
- isolate reaction pathways leading to that configuration,
- suppress competing transformations,
- and optimize conditions for its preservation.

This procedure replaces the problem of transformation within an environment by the problem of directed synthesis under constrained conditions.

As a result, the laboratory setting does not approximate prebiotic environments, but instead implements a fundamentally different epistemic regime: one in which configurations are treated as goals rather than as intermediate states in a continuous transformation process.

Within FCF, such target-oriented reconstruction eliminates precisely those features that are structurally essential, namely:

- heterogeneity of the medium,

- concurrent and competing transformations,
- and persistence of transformation regimes rather than individual configurations.

Formal Consequence: Non-Invariance of Targeted Synthesis Within the Filtered Configuration Framework, the object of interest is not an isolated configuration $c \in C$, but an environment-dependent transformation process T_E acting on C .

Laboratory reconstruction replaces this structure by a mapping of the form:

$$L : \emptyset \rightarrow c^*$$

where c^* is a predefined target configuration, and L denotes a controlled procedure optimized to produce c^* under constrained conditions.

In contrast, natural processes are described by:

$$T_E : C \rightarrow \mathcal{P}(C)$$

where configurations emerge as elements of transformation trajectories rather than as predefined targets.

Proposition (Non-Invariance of Targeted Synthesis). Target-oriented synthesis is not invariant under environment-dependent transformation. That is, there does not exist, in general, a mapping L such that

$$c^* \in T_E(c_0) \iff L(\emptyset) = c^*$$

for a given environment E .

Interpretation. The existence of a laboratory procedure producing c^* does not imply that c^* is a natural attractor or even a typical intermediate within the transformation regime T_E .

Proof (Sketch). Laboratory procedures isolate and optimize specific reaction pathways while suppressing competing transformations. In contrast, T_E includes all concurrent and interacting processes induced by environment E .

Therefore, L is not equivalent to T_E , but corresponds to a constrained projection of it:

$$L \approx T_E \Big|_{\text{restricted pathways}}$$

Since restriction alters the structure of the transformation space, the resulting set of configurations is not invariant under this projection. Hence, the presence of c^* in the image of L does not imply its presence, stability, or relevance within T_E . \square

Corollary (Epistemic Mismatch). Success in constructing a configuration under laboratory conditions does not provide evidence that the same configuration is generable, typical, or relevant within the corresponding environmental transformation regime.

Implication. Experimental reconstruction cannot be used as a direct proxy for prebiotic processes, unless invariance between L and T_E is explicitly established.

This establishes that laboratory synthesis and prebiotic transformation belong to distinct operator classes and must not be conflated.

Conclusion These three forms of epistemic misplacement lead to a common distortion: the search for specific modern biomolecules as primary targets of abiogenesis.

Within FCF, this approach is inverted. The relevant question is not how particular molecules were generated in isolation, but how configurations were continuously transformed, filtered, and stabilized within complex environments.

Accordingly, abiogenesis should be understood as the emergence of environment-dependent transformation regimes, from which currently observed biochemical structures represent only a filtered and historically contingent subset.

The search for specific molecules as necessary precursors of life is therefore an artifact of epistemic projection rather than a consequence of the underlying physical process. These misplacements do not merely introduce minor inaccuracies, but fundamentally alter the structure of the problem, transforming a question of filtered persistence into an ill-posed problem of targeted molecular generation.

7 Observability as a Constraint (COE Perspective)

Within Coherent Observational Epistemology (COE), observation is not treated as passive access to reality, but as an interaction constrained by locality, interface structure, and coherence conditions.

Let E denote an environment of physical survival and I denote an observational interface (measurement conditions, detection mechanisms, and coherence constraints).

Define an observability operator:

$$O_{E,I} : \mathcal{C} \rightarrow \{0, 1\}$$

such that

$$O_{E,I}(c) = \begin{cases} 1, & \text{if configuration } c \text{ is both stable under } E \text{ and detectable via } I \\ 0, & \text{otherwise} \end{cases}$$

We can express this as:

$$O_{E,I}(c) = S_E(c) \wedge C_I(c)$$

where $S_E(c)$ is the survival operator (Axiom 1) and $C_I(c)$ is a coherence/detectability condition imposed by the observational interface.

The empirically accessible set is therefore:

$$\mathcal{O}_{E,I} = \{c \in \mathcal{C} \mid O_{E,I}(c) = 1\}$$

Interpretation

Observation is doubly constrained:

- Physical constraint: configurations must survive under environment E .

- Epistemic constraint: configurations must satisfy coherence and detectability conditions imposed by interface I .

Thus, environmental filtering operates not only at the level of physical survival, but also at the level of epistemic accessibility.

Remarks

- In general,

$$\mathcal{O}_{E,I} \subseteq \mathcal{O}_E \subseteq \mathcal{C}$$

reflecting successive filtering by survival and observability.

- There may exist configurations such that

$$S_E(c) = 1 \wedge C_I(c) = 0,$$

i.e., configurations that physically survive but remain unobservable.

- There may also exist configurations such that

$$G_{E'}(c) = 1 \wedge S_E(c) = 0,$$

i.e., configurations that were generated elsewhere but leave no recoverable trace under current conditions.

Conclusion

The empirical record is inherently biased. It does not represent the full space of generable or even survivable configurations, but only those that simultaneously satisfy survival and observability constraints.

Therefore, the absence of a configuration in observational data does not constitute evidence of its impossibility, but only of its incompatibility with the combined constraints of environment and observation.

8 Panspermia as a Natural Consequence of FCF

Within the Filtered Configuration Framework (FCF), the question of origin is separated from the question of observability.

From Theorem 1, observability under an environment E does not imply local generability:

$$c \in \mathcal{O}_E \not\Rightarrow c \in \mathcal{G}_E$$

This directly implies that configurations observed in a given environment may have been generated under different environmental conditions.

Interpretation

FCF does not require or assume external origin. However, it establishes that:

- external generation is logically consistent,
- transfer across environments is compatible with the framework,
- and selective survival determines what remains observable.

Transfer Model

Let E_g denote an environment of generation and E_s an environment of survival. Then:

$$c \in \mathcal{G}_{E_g}, \quad c \notin \mathcal{G}_{E_s}, \quad c \in \mathcal{O}_{E_s}$$

is a valid configuration trajectory.

This corresponds to:

- formation in E_g ,
- transfer,
- partial survival under E_s .

Implication

Panspermia emerges not as a speculative hypothesis, but as a natural consequence of the decoupling between generation and survival.

FCF neither asserts nor denies external origin; it removes the logical constraint that origin must be local.

9 Extended Epistemic Filtering

The Filtered Configuration Framework can be extended by incorporating results from interface-based epistemology and temporal ontology.

Observed structures are not only subject to environmental filtering and generation–survival decoupling, but also to epistemic constraints arising from the reconstruction of events and the non-invertibility of observational interfaces.

In particular:

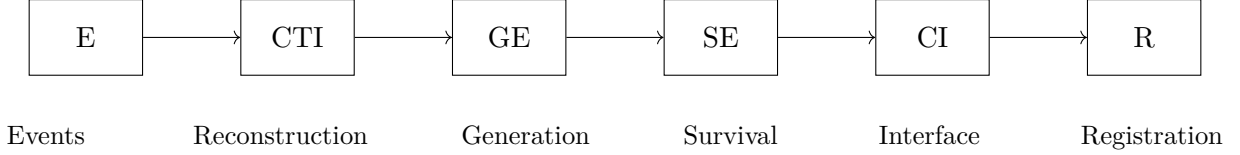
- the sequence of events precedes any formal representation (temporal independence),
- observation produces structured traces rather than direct access to sources,
- multiple generative configurations may correspond to identical observations.

Thus, the observable domain is shaped not only by physical survivability, but also by epistemic accessibility constraints.

10 Extended Filtering Structure

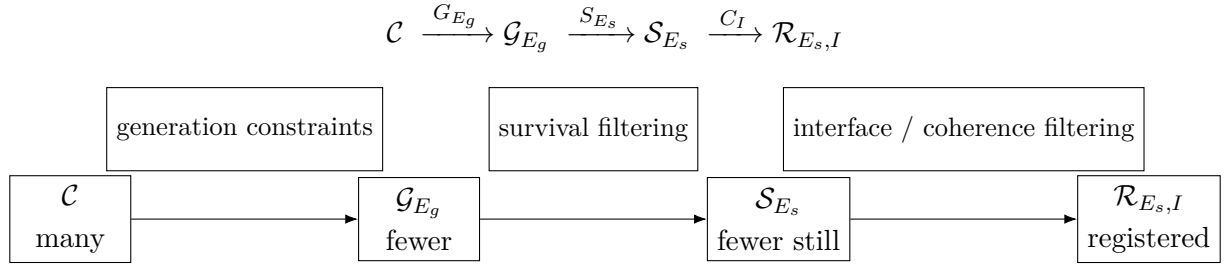
The Filtered Configuration Framework can be extended to include epistemic constraints arising from reconstruction and observation. In this extended form, the observable domain is shaped not only by physical processes, but also by the structure of description and measurement.

Filtering Chain



Formal Representation

The extended filtering process can be expressed as a composition of operators:



Interpretation

- \mathcal{C} : space of possible configurations,
- \mathcal{G}_{E_g} : configurations generable under environment E_g ,
- \mathcal{S}_{E_s} : configurations survivable under environment E_s ,
- $\mathcal{R}_{E_s, I}$: configurations registered under survival conditions E_s and interface constraints I ,
- G_{E_g} : generation operator,
- S_{E_s} : survival operator,
- C_I : interface/coherence operator.

Extended Interpretation

In addition to physical filtering, two epistemic constraints must be taken into account:

- **CTI (Constructive Temporal Interval)**: formal representations arise only after events and therefore cannot be treated as the ontological source of those events[2],

- **Interface non-invertibility:** observation does not uniquely recover origin, since multiple generative configurations may correspond to the same registration[3].

Accordingly, the empirically accessible domain is determined by a cascade of constraints:

events \rightarrow reconstruction \rightarrow generable \rightarrow survivable \rightarrow registered

Consequence

This structure implies that the absence of configurations in empirical data may result from filtering at any stage of the chain, including generation, survival, reconstruction, or registration constraints.

Therefore, the observable biochemical landscape is not a direct reflection of generative processes, but a highly constrained projection shaped by both physical and epistemic filters.

11 Conclusion

We have introduced the *Filtered Configuration Framework* (FCF), a formal perspective in which observable structures are understood as the result of successive filtering processes acting on a broader configuration space.

Within this framework, empirically accessible configurations are determined by four distinct but coupled factors: generation (what can be formed), environment-dependent transformation (how configurations evolve within an environment), survival (what can persist), and observability (what can be detected). These factors do not coincide and, in general, operate under different environmental and epistemic regimes.

From this, we have shown that:

- observability does not imply local generability,
- absence does not imply impossibility,
- and the observable domain is systematically non-representative of the underlying configuration space due to successive filtering processes.

As a consequence, life as observed on Earth should not be interpreted as a direct reflection of generative processes, but as a filtered outcome: a subset of configurations that have emerged, transformed, and remained compatible with terrestrial conditions.

This perspective dissolves the apparent tension between local abiogenesis and external origin scenarios. The framework does not require commitment to either, but demonstrates that both are compatible with the same underlying structure.

More generally, FCF implies that scientific observation is intrinsically selective: what is accessible is not the space of the possible, but the space of the compatible.

A further consequence is epistemic. The construction of specific configurations under controlled laboratory conditions does not establish their generative relevance within natural environments.

Constructive procedures and environment-dependent transformation processes belong to distinct operator classes and are not, in general, invariant.

Thus, the problem of abiogenesis is fundamentally reframed. It is not solely a question of how particular molecular structures were generated, but of how configurations are generated, transformed, filtered, and rendered observable across environments and time.

In this extended view, the observable domain is not a direct image of reality, but the result of successive constraints imposed by generation, transformation, survival, and observation. The absence of structures in empirical data therefore reflects not only physical impossibility, but also epistemic inaccessibility.

Abiogenesis is not underdetermined by probability, but overdetermined by filtering.

A Probabilistic Formulation of Environmental Filtering

We extend the deterministic framework by introducing a probabilistic structure over the configuration space.

Let $(\mathcal{C}, \mathcal{F}, \mu)$ be a measurable space, where μ defines a baseline measure over configurations (e.g., generative or structural prior).

Generation Probability

Define a generation probability under environment E_g :

$$P_G(c | E_g)$$

representing the likelihood that configuration c is formed under E_g .

This induces a measure:

$$\mu_G(A | E_g) = \int_A P_G(c | E_g) d\mu(c)$$

Survival Probability

Define a survival probability:

$$P_S(c | E_s)$$

representing the likelihood that configuration c remains stable under environment E_s .

This induces:

$$\mu_S(A | E_s) = \int_A P_S(c | E_s) d\mu(c)$$

Observability Probability

Let I denote the observational interface. Define a detectability (coherence) probability:

$$P_C(c | I)$$

Then the probability of observing configuration c is:

$$P_O(c | E_s, I) = P_S(c | E_s) \cdot P_C(c | I)$$

Combined Model

If generation, survival, and observability are composed, the full pipeline becomes:

$$P(c | E_g, E_s, I) = P_G(c | E_g) \cdot P_S(c | E_s) \cdot P_C(c | I)$$

Interpretation

This factorization highlights three independent constraints:

- Generation bias: which configurations are likely to form.
- Survival bias: which configurations persist.
- Observability bias: which configurations are detectable.

Consequence (Selection Bias)

The observed distribution is not the generative distribution:

$$P_O(c) \neq P_G(c)$$

Instead, it is a reweighted distribution:

$$P_O(c) \propto P_G(c) \cdot P_S(c) \cdot P_C(c)$$

Thus, empirical observations reflect a multiply filtered subset of the underlying configuration space.

Implication

Configurations with high generative probability but low survival or detectability may never be observed. Conversely, configurations with low generative probability but high survival and detectability may dominate the observed space.

This reinforces the central claim: the observable biochemical landscape is a biased projection of a much larger space of possible configurations.

Logarithmic Form (Additive Decomposition)

Taking the logarithm of the combined probability:

$$\log P(c | E_g, E_s, I) = \log P_G(c | E_g) + \log P_S(c | E_s) + \log P_C(c | I)$$

This transforms multiplicative filtering into an additive structure, where each term contributes independently.

Energy-like Interpretation

Define an effective energy functional:

$$\mathcal{E}(c) = -\log P(c | E_g, E_s, I)$$

Then:

$$\mathcal{E}(c) = \mathcal{E}_G(c) + \mathcal{E}_S(c) + \mathcal{E}_C(c)$$

where

$$\mathcal{E}_G(c) = -\log P_G(c | E_g), \quad \mathcal{E}_S(c) = -\log P_S(c | E_s), \quad \mathcal{E}_C(c) = -\log P_C(c | I)$$

Interpretation

- \mathcal{E}_G represents generative difficulty (rarity of formation).
- \mathcal{E}_S represents instability under environmental conditions.
- \mathcal{E}_C represents observational inaccessibility.

Configurations with lower total $\mathcal{E}(c)$ dominate the observed space.

Connection to Statistical Mechanics

This formulation is analogous to Boltzmann-type distributions:

$$P(c) \propto e^{-\mathcal{E}(c)}$$

Thus, the observable configuration space can be interpreted as a statistical ensemble shaped by combined energetic constraints of generation, survival, and observation.

Entropy and Information

Let $P_O(c)$ denote the observed distribution:

$$P_O(c) \propto P_G(c) \cdot P_S(c) \cdot P_C(c)$$

Define entropy:

$$H_O = - \sum_{c \in \mathcal{C}} P_O(c) \log P_O(c)$$

Then:

- Environmental filtering reduces entropy relative to the generative distribution.
- Observability introduces an additional compression of accessible configurations.

Relative Entropy (Information Loss)

Let $P_G(c)$ denote the generative distribution. Then the divergence:

$$D_{\text{KL}}(P_O \parallel P_G)$$

measures the information loss induced by survival and observability filtering.

Implication

The observed configuration space is not only a filtered subset, but also an information-compressed representation of the generative space.

Thus, absence of configurations corresponds not only to physical elimination, but to loss of informational accessibility.

Summary

- Multiplicative filtering \rightarrow additive energy decomposition.
- Observed structures correspond to low-energy configurations under combined constraints.
- Entropy reduction reflects environmental and epistemic filtering.

Time Evolution (Dynamics)

We extend the framework by introducing time dependence into generation, survival, and observability.

Let $t \in \mathbb{R}_{\geq 0}$ denote time.

Define time-dependent probabilities:

$$P_G(c, t), \quad P_S(c, t), \quad P_C(c, t)$$

Then the observable distribution evolves as:

$$P_O(c, t) \propto P_G(c, t) \cdot P_S(c, t) \cdot P_C(c, t)$$

Master Equation Form

Let $P(c, t)$ denote the probability of configuration c at time t . Its evolution can be written as:

$$\frac{dP(c, t)}{dt} = \underbrace{R_G(c, t)}_{\text{generation}} - \underbrace{R_D(c, t)}_{\text{decay}} + \underbrace{\sum_{c' \in \mathcal{C}} W(c' \rightarrow c) P(c', t) - W(c \rightarrow c') P(c, t)}_{\text{transformation}}$$

where:

- $R_G(c, t)$ is the rate of formation,
- $R_D(c, t)$ is the rate of degradation,
- $W(c' \rightarrow c)$ is the transition rate between configurations.

Environmental Dependence

All terms depend implicitly on the environment:

$$R_G = R_G(E_g(t)), \quad R_D = R_D(E_s(t)), \quad W = W(E(t))$$

Thus, environmental change induces evolution in the configuration distribution.

Effective Energy Dynamics

Using the energy representation:

$$\mathcal{E}(c, t) = -\log P(c, t)$$

we obtain:

$$\frac{d\mathcal{E}(c, t)}{dt} = -\frac{1}{P(c, t)} \frac{dP(c, t)}{dt}$$

which captures how configurations become more or less accessible over time.

Stability and Persistence

A configuration c is dynamically stable if:

$$\frac{dP(c, t)}{dt} \approx 0$$

and unstable if:

$$\frac{dP(c, t)}{dt} \ll 0$$

Thus, survival corresponds to persistence in time under environmental constraints.

Transient Configurations

There may exist configurations such that:

$$\exists t_0 : P(c, t_0) > 0, \quad \lim_{t \rightarrow \infty} P(c, t) = 0$$

These configurations are generated but do not persist and therefore may leave no observable trace.

Implication

The observable configuration space is not only filtered but also time-dependent. It represents a dynamically evolving subset of configurations shaped by generation, transformation, and decay processes under changing environmental conditions.

Thus, absence in observation may reflect not only incompatibility with current conditions, but also temporal disappearance.

Connection to Evolution (Fitness as a Special Case)

Biological evolution can be interpreted as a specific instance of the general framework, where configurations correspond to replicating structures (e.g., molecules, cells, organisms).

Let $c \in \mathcal{C}$ denote a replicating configuration. Define its fitness as the net growth rate:

$$F(c, t) = R_G(c, t) - R_D(c, t)$$

where:

- $R_G(c, t)$ is the replication or production rate,
- $R_D(c, t)$ is the decay or removal rate.

Then the evolution of $P(c, t)$ can be approximated by:

$$\frac{dP(c, t)}{dt} = F(c, t) P(c, t)$$

Interpretation

- $F(c, t) > 0$ corresponds to expanding configurations.
- $F(c, t) < 0$ corresponds to vanishing configurations.

Thus, fitness is not an independent principle, but an emergent property of generation and survival dynamics.

Relation to Filtering

From the general framework:

$$P_O(c, t) \propto P_G(c, t) \cdot P_S(c, t) \cdot P_C(c, t)$$

fitness can be interpreted as the logarithmic time derivative of the combined probability:

$$F(c, t) \approx \frac{d}{dt} \log P(c, t)$$

Thus, configurations with increasing probability correspond to positive fitness.

Selection as Filtering

Natural selection corresponds to differential survival and replication:

$$F(c, t_1) > F(c', t_1) \Rightarrow P(c, t_2) > P(c', t_2)$$

for $t_2 > t_1$.

This is a dynamic manifestation of environmental filtering.

Implication

Evolution does not introduce a fundamentally new principle. It represents a special case of the general filtering framework, where:

- generation corresponds to replication,
- survival corresponds to persistence,
- fitness corresponds to the net rate of change.

Conclusion

Biological evolution can be understood as a constrained dynamical process within the broader configuration space. The apparent directionality and adaptation arise from the same underlying mechanisms of generation, survival, and filtering.

Thus, fitness is not a primitive concept, but a derived quantity within the general framework.

B Examples Beyond Biology

The Filtered Configuration Framework applies not only to biological systems, but to physical and chemical structures in general.

Phase Transitions

Structures such as phases of matter emerge only under specific conditions (e.g., pressure, temperature), but may persist or disappear when conditions change. Certain transient phases leave no observable trace.

Crystalline Structures

Crystals form under constrained conditions but remain stable under others. Many possible lattice configurations are never observed due to instability or formation constraints.

Plasma Structures

Plasma configurations (e.g., filaments, self-organizing patterns) arise under specific energetic conditions and often dissipate rapidly outside them.

Autocatalytic Networks

Chemical reaction networks may form under narrow conditions and collapse when environmental parameters change. Many such networks may remain unobserved due to instability or lack of detectability.

Conclusion

These examples illustrate that FCF is not specific to life, but reflects a general principle:

observable structures are those that survive and remain coherent under both environmental and observational constraints.

C Medium-Dependent Transformation and Productive Decay

Motivation

Standard discussions of abiogenesis often evaluate candidate configurations in terms of their intrinsic stability under isolated conditions. Within the Filtered Configuration Framework (FCF), such an approach is incomplete.

Configurations do not exist in isolation, but as elements of environment-dependent transformation processes. Consequently, the relevant object of analysis is not a configuration $c \in C$ alone, but the pair (c, E) , where E denotes the environment.

Transformation Operator

Let C denote the space of configurations and E an environment. We define a transformation operator:

$$T_E : C \rightarrow \mathcal{P}(C),$$

such that

$$T_E(c) = \{c'_1, c'_2, \dots\}$$

is the set of configurations produced from c under environment E .

This generalizes the notion of decay: instead of treating instability as elimination, we treat it as transformation into other configurations.

Eliminative vs Productive Decay

Let $L : C \rightarrow \mathbb{R}$ denote a measure of structural connectivity or relational integration.

We distinguish two regimes:

- **Eliminative decay:**

$$\mathbb{E}[L(c')] < L(c), \quad c' \in T_E(c),$$

corresponding to net loss of structural integration.

- **Productive decay:**

$$\mathbb{E}[L(c')] > L(c), \quad c' \in T_E(c),$$

corresponding to net increase in structural integration.

In the productive regime, the instability of a configuration contributes to the formation of more structurally integrated configurations.

Medium-Dependent Persistence

Under this formulation, persistence is not restricted to individual configurations. Instead, persistence may occur at the level of transformation regimes.

Let \mathcal{T}_E denote a family of transformations induced by environment E . We say that a regime is persistent if repeated application of transformations produces configurations that remain within a subset $S \subset C$ compatible with environmental constraints.

Thus, persistence may be expressed as:

$$c \xrightarrow{T_E} c' \xrightarrow{T_E} c'' \xrightarrow{T_E} \dots \quad \text{with } c^{(n)} \in S.$$

This generalizes the survival operator SE : instead of requiring

$$SE(c) = 1,$$

we allow persistence through transformation sequences.

Relation to Environmental Filtering

Within FCF, environmental filtering is expressed through the survival operator SE . The present extension suggests that SE should be interpreted more broadly:

- not only as preservation of configurations,
- but also as compatibility of transformation pathways with environment E .

Thus, a configuration may be eliminated as an identifiable entity while still contributing to configurations that remain within the observable domain.

Illustrative Regime

Consider a chemically rich environment subject to intermittent energy input (e.g., radiation or electrical discharge). Complex organic configurations may:

- undergo partial breakdown,
- form carbon-rich residues,
- generate new bonds and cross-linked structures,
- produce heterogeneous, increasingly structured media.

In such regimes, repeated transformation does not lead to complete elimination, but to progressive reconfiguration of the medium. Local instability of individual configurations may therefore coexist with global increase in structural integration.

Implication for Abiogenesis

Objections to abiogenesis based solely on the instability of specific molecular configurations are underdetermined. Within a medium-dependent framework, instability does not imply absence of contribution.

The relevant question is not whether a configuration persists in isolation, but whether its transformation under environment E contributes to configurations that remain within the filtered domain.

Accordingly, abiogenesis should be understood not only in terms of generation and survival of configurations, but also in terms of environment-dependent transformation processes that shape the accessible configuration space.

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