Conjecture: The Theory of Everything is Embodied by Fundamental Replicators (Femes)

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Abstract

This paper conjectures that fundamental reality, taken to be an interacting system composed of discrete information, embodies replicating information structures called femes. These femes are posited to interact to cause the laws of physics. We therefore extend Universal Darwinism to propose the existence of four abstract replicators: femes, genes, memes, and temes.
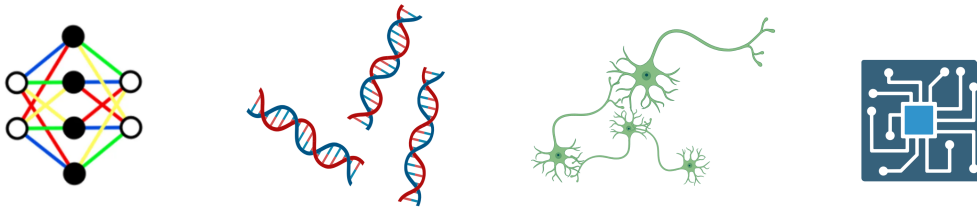
Figure 1: The four replicators conjectured to exist in reality.

We firstly consider the problem of fine-tuning, and problems with current solutions. A detailed background section outlines key principles from physics, computation, evolutionary theory, and constructor theory. The conjecture is then provided in detail, along with five falsifiable predictions.

Contents

1 The Fine-Tuning Problem

Modern physics seeks a unified framework that describes the fundamental forces and particles in the universe.

Theory of Everything (ToE)   a single equation or algorithm that accurately describes the form and dynamics of reality at all scales.

This work aligns with paradigms in physics where reality and the ToE are composed of discrete information. Notable examples include the Wolfram Physics Project.

Wolfram Physics Project   a theory where reality is composed of discrete information interacting on a hyper-graph, with rewrite rules that create emergent dynamics consistent with General Relativity (GR) and Quantum Mechanics (QM)[1].

The fine-tuning problem arises: why does this specific ToE exist, instead of some other structure from the vast combinatorial space resulting from varying the laws and constants?

Fine-Tuning   the question of why the ToE has a form that causes the evolution of complex life, and why this form persists through time.

Occam's razor states that the explanation with the fewest assumptions is most likely to be correct. We use this principle to analyze two explanations of fine-tuning.

Explanations

The Null Hypothesis

The Null Hypothesis posits that no further explanation is required for the initial conditions and laws of the universe. It assumes:

– The ToE exists with the observed laws and parameters.

– Information was instantiated with a specific form at the beginning of the Big Bang, including parameters from inflationary models, without further causal explanation.

The Anthropic Principle

The anthropic principle suggests that the laws of the universe are conducive to life because only such a universe could be observed by life forms like us[2]. This principle assumes:

– Our universe is one of many, that exist as a consequence of a larger structure (e.g., multiverse)

– The multiverse has a specific form that results in our ToE and initial conditions.

This principle shifts the fine-tuning problem rather than solving it. No structure—even an infinite one—can embody all possible information states. Every infinite set can be embedded in a larger one, implying that an infinite multiverse still requires specific explanations for why certain subsets, such as those supporting life and complex structures like our universe, are realized over others[3, 4].

Explanation by Evolution

This paper proposes an evolutionary explanation for fine-tuning, requiring only two assumptions:

– Significant information exists.

– Interaction is universal / Turing complete.

2 Background

This section introduces a generalized theory of the dynamics of information systems, largely based on constructor theory by Deutsch and Marletto [5, 6, 7, 8, 9].

2.1 Information and Interaction

Information is defined by its counterfactual potential, an idea in constructor theory.

Information   has counterfactual potential.

Counterfactual potential   the potential for information to be different.

For example, the answer to a simple yes/no question is information because there is more than one possible outcome. To demonstrate, consider a black/white square and a function that asks for the color of the square, f('are you white'). The function returns black if the answer is true and white if the answer is false. In the diagram below, changing either the function or the square's color changes the output of the interaction. Both the function and the data are considered information. By this definition, mass, energy, and anything that exists in reality are information.
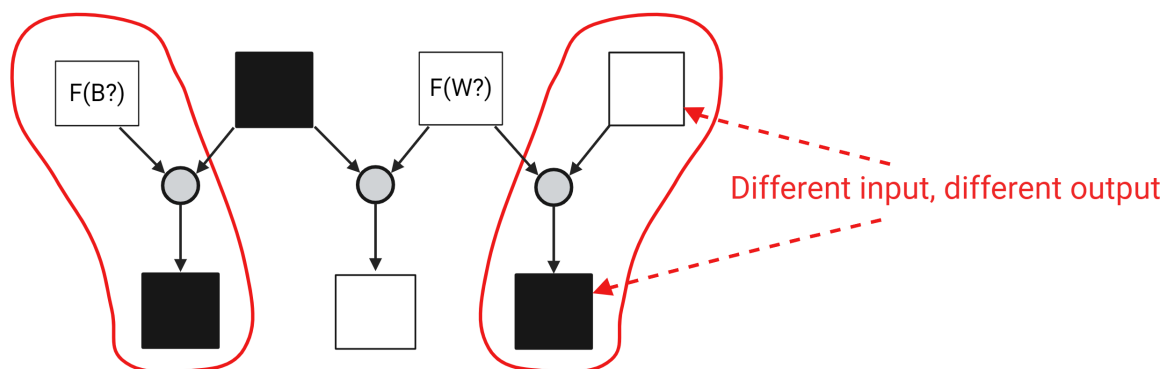

Figure 2: The counterfactual potential of information.

Interaction   the process by which information structures create new structures, where the output structure is causally dependent on the input structure's information.

2.2   Universality and Turing Completeness

A set of functions is universal or Turing complete if it can perform any computation, given sufficient time and memory.

Universality / Turing Completeness   a characteristic of a set of operators that can be composed to perform any computation[4].

A set of 'NAND' gates is universal. They perform non-linear transformations on information, meaning the input and output structures can be of any size.
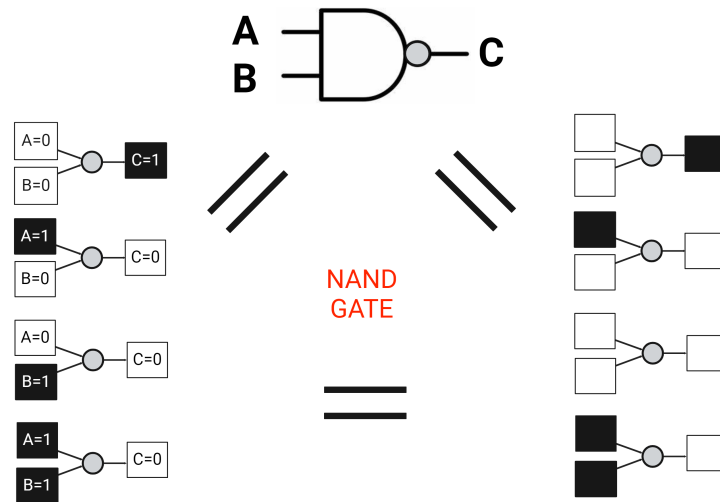
Figure 3: Equivalent representations of the possible input/output of a NAND gate.

Computational Equivalence (Wolfram)
/ Interoperability (Deutsch)   Any universal system, including reality, can interact identically to any other universal system, given sufficient time and memory. Wolfram calls this computational equivalence, while Constructor Theory calls it interoperability.
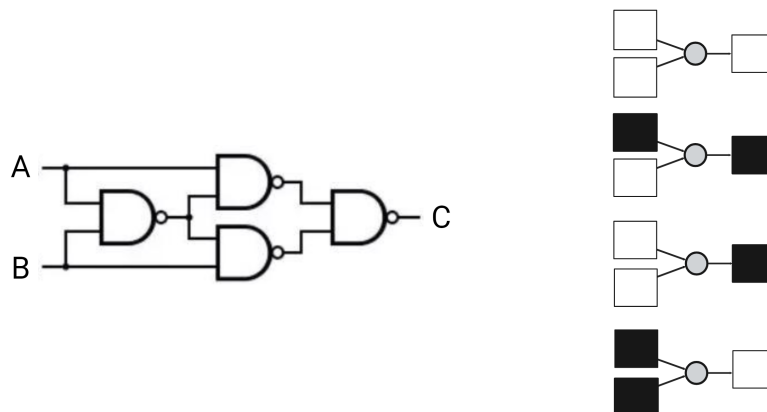
Figure 4: NAND gates composed to form an XOR gate, another universal gate.

2.3   Systems

System   Information interacting repeatedly.

An example is when the $f(\square?)$ interacts with a square repeatedly. In Figure 5, $f(\square?)$ causes 4 transformations on the square. The three representations of this system are equivalent.
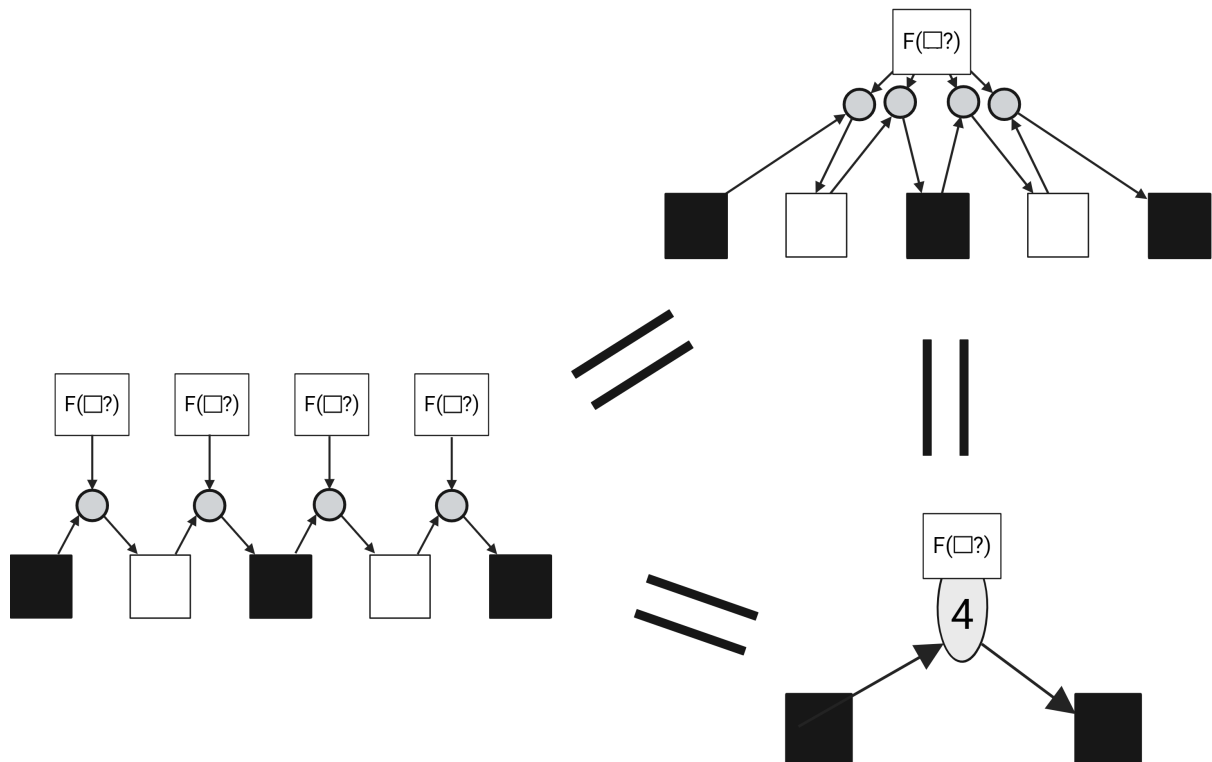

Figure 5: A system where $f(\square?)$ interacts with a square repeatedly.

Time is considered to result from repeated interaction of information. Systems permitting non-linear transformations can generate infinite novelty with sufficient time and memory, e.g., computing the digits of pi. Reality is a system that can generate infinite novelty.

Structure   Information of some finite description, that exists at some point in time.

Environment   The system that some information structure interacts with.

2.4 Abstraction and Emergence

Emergence   Structures can interact to cause novel transformations that do not exist in the constituent information.

In Figure 6, we see the emergent information structure of the Glider, which has the property of moving $\sqrt{2}$ grid cells diagonally every 4 interactions of the $f(\text{GoL})$.
The Game of Life consists of a grid where each cell is updated by $f(\text{GoL})$. $f(\text{GoL})$ determines if the cell is black or white in the next update, which is dependent on the number of black/white neighbors. If unfamiliar, please use this visualisation [10].
The Glider is an abstract/emergent structure as it allows us to understand the dynamics of the system in a numerically reducible manner.
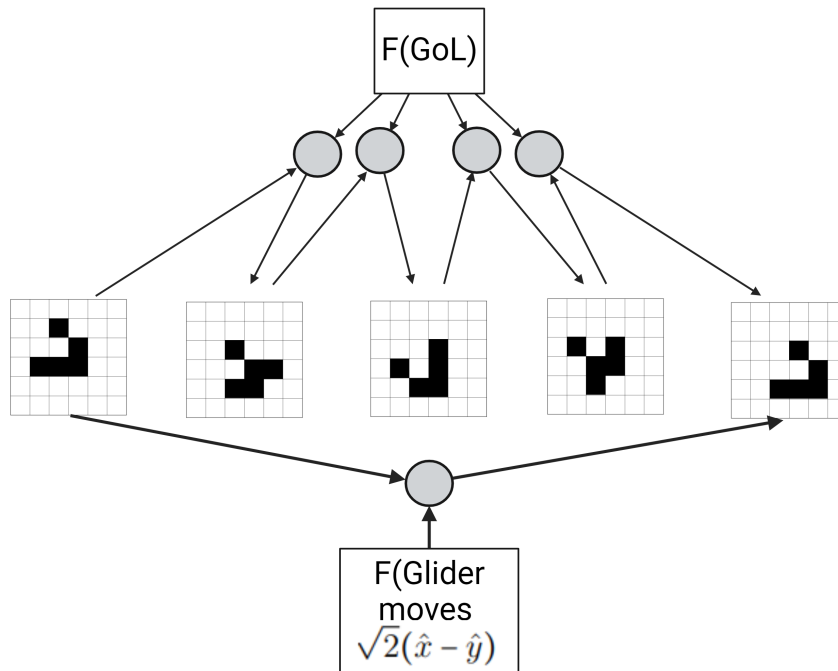

Figure 6: The glider moves $\sqrt{2}$ grid cells every 4 interactions with the $f(\text{GoL})$

Numerically reducible (Wolfram)
/ Tractable (Deutsch)   Understanding the dynamics of a system by interactions of abstract objects. These abstract objects can interact to give the same output of interaction as the fundamental update rule. The term reducible is used as information that exists in the future is predicted by less computationally expensive means.

The Wolfram Physics Project and Constructor Theory both highlight how complex systems can be understood through simple, abstract rules. Deutsch describes how dominoes can be arranged to run the addition operation. It is possible to predict and explain the outcome of domino interaction by considering the fundamental molecular dynamics, or by carrying out the addition operation. This is directly linked to the concepts of interoperability and computational equivalence. Systems like molecular dynamics embody universal operators. They can therefore be composed to simulate any computation, like number addition.

2.5 Knowledge

Knowledge   Any structure that tends to remain in an environment once instantiated.

Constructor theory focuses on the concept of knowledge propagation as a key principle for the general dynamics of information systems. We have encountered a structure that embodies knowledge - the glider. It tends to remain once instantiated. In general, when information interacts, knowledge propagates.

Properties of Knowledge

− *Knowledge is hard to vary and come by*
  Figure 7 shows that only 9/512 of the possible 3x3 grids will propagate upon interaction with $f(\text{GoL})$ on a larger empty grid.
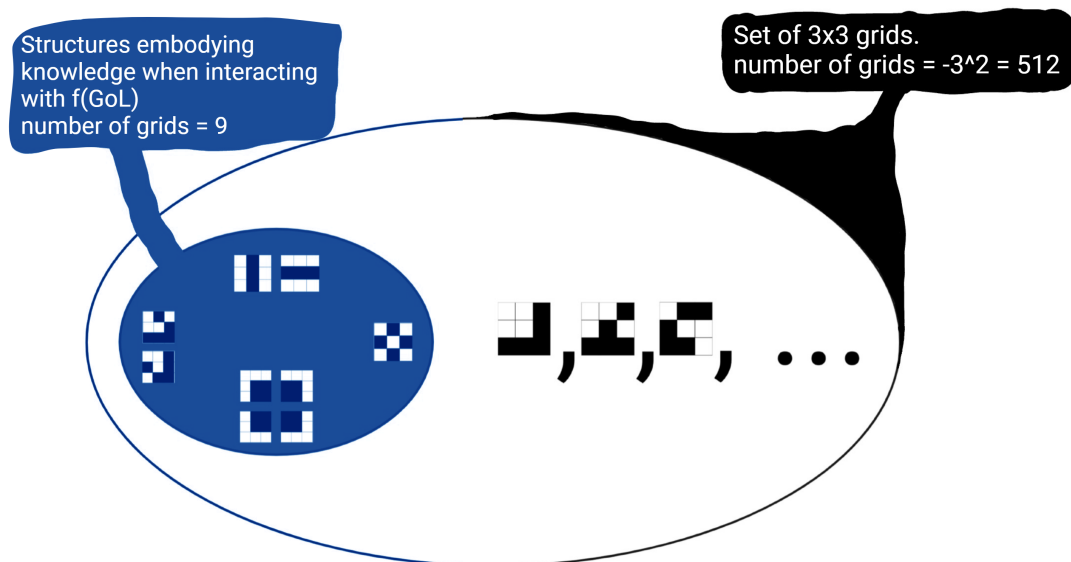

Figure 7: Only a subset of grids are knowledge in this environment.

− *Knowledge is parochial and fallible.*
  Any knowledge fails to propagate upon interaction with an infinite subset of the infinite possible information structures. The term parochial describes how any knowledge will only propagate on some subset of possible environments. The knowledge in the glider is fallible and parochial as shown in Fig 8 below.
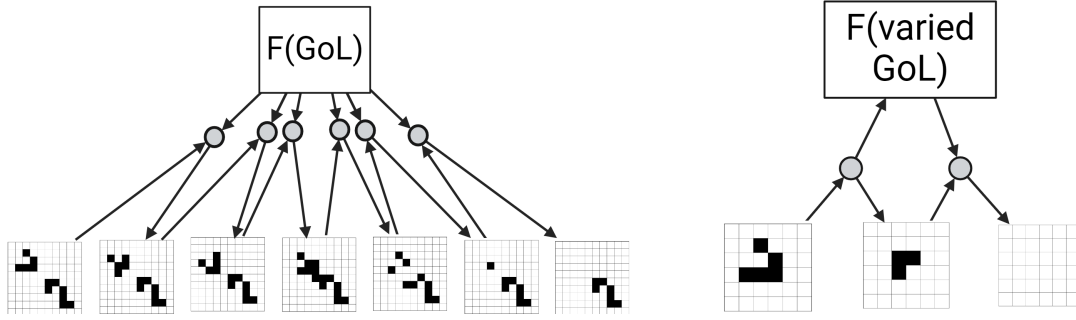
Figure 8: Glider fails to propagate when interacting with the Eater, or with different update rules.

Fallibility is expressed in computer science by the No Free Lunch (NFL) theorem [11], which states that no algorithm A or B has universally superior performance across all problems P:

If we consider that an algorithm is a form of knowledge (it tends to remain in computer memory), we have the equivalent result, where no knowledge k has universally superior performance across all problems P. All knowledge is fallible. Equation 1 - No Free Lunch Theorem.

$$\frac{1}{|P|} \sum_{p \in P} E(A, p) = \frac{1}{|P|} \sum_{p \in P} E(B, p) \tag{1}$$

- *Problems are inevitable and soluble*

In Deutsch's 'The Beginning of Infinity' he describes how the concept of knowledge leads to two general principles for any structure that embodies knowledge:

1. Problems are inevitable - any structure will fail to propagate upon interaction with an infinite number of structures, from the infinite set of possible structures.

2. All problems are soluble - any structure from the infinite set of destructive structures is itself fallible, and can be overcome with some knowledge.

Problem   is defined parochially with respect to some knowledge, as any structure that will destroy the knowledge, causing it not to remain in the environment.

9

2.6 Constructors

Constructor   A structure that embodies knowledge that causes it to remain identical before and after some interaction.

A constructor embodies knowledge for causing some finite number of transformations when interacting with some environment.

Repertoire   The finite set of transformations a structure embodies knowledge for causing, in a given environment.

Both the Glider and the Eater are constructors. Catalysts, enzymes, and DNA are examples observed in reality. Below is an example where Platinum acts as a constructor - causing some transformation and returning to the same form.
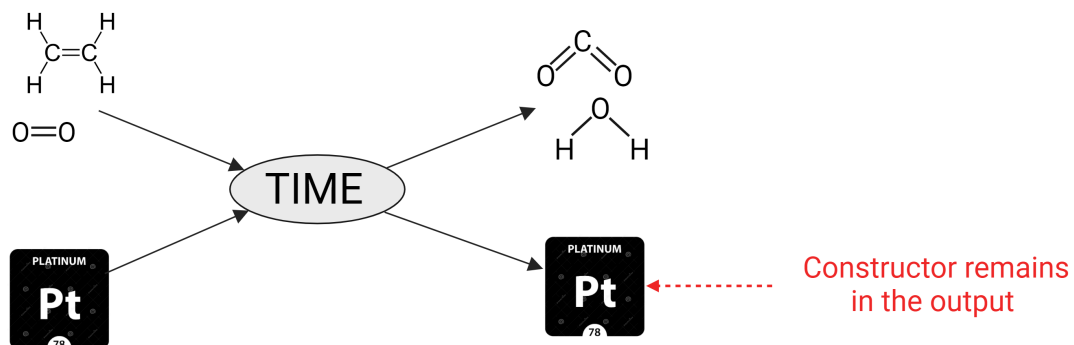

Figure 9: Platinum as a catalyst in the reaction: $C_xH_y + \left(x + \frac{1}{4}y\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$.

The Game of Life rules are only constructors when the environment includes the computer memory, as shown below.
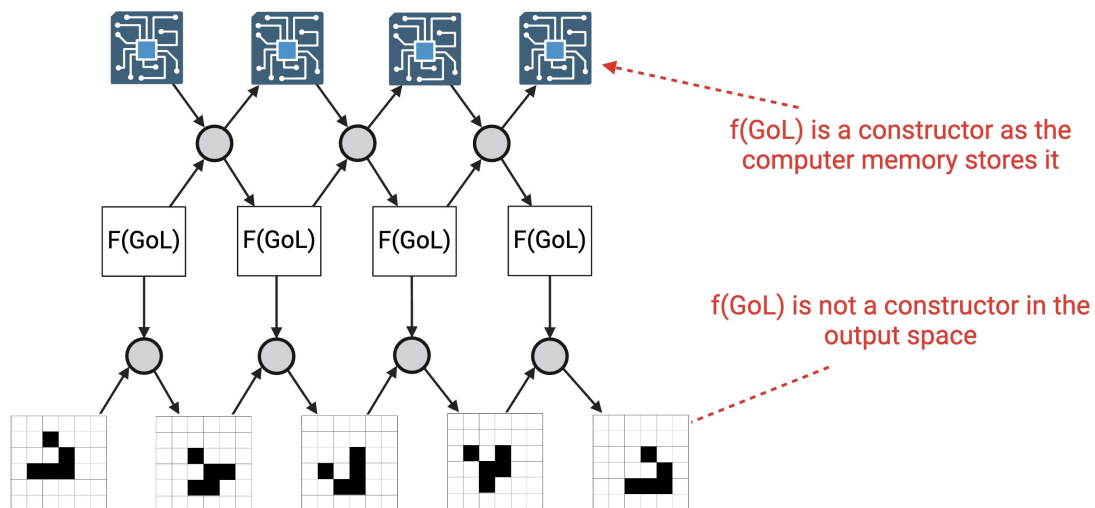

Figure 10: The GoL rules are not constructors, unless we consider the environment of the computer memory and reality.

Properties of Constructors

– *All properties of knowledge*

– *Possible and impossible transformations:*

There are possible and impossible transformations for any constructor, due to the constraint of returning to the same form after interaction. Perpetual motion or alchemy are examples of impossible transformations.
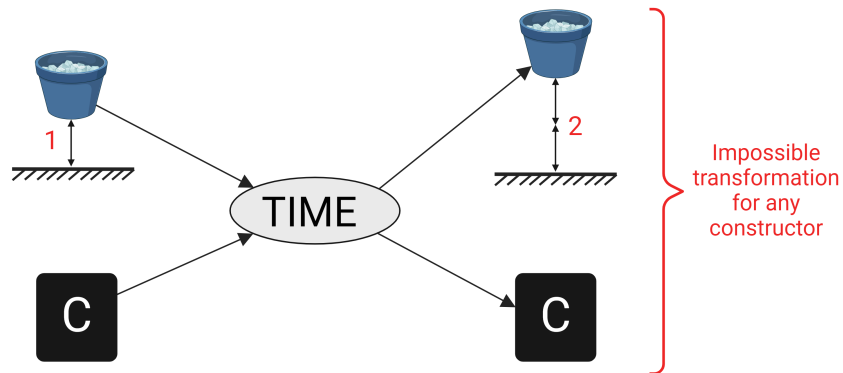

Figure 11: No constructor can return to initial form after losing energy.

2.7 Replicators

Replicator   Constructors able to cause the transformation of creating a copy of themselves in the environment they interact with.
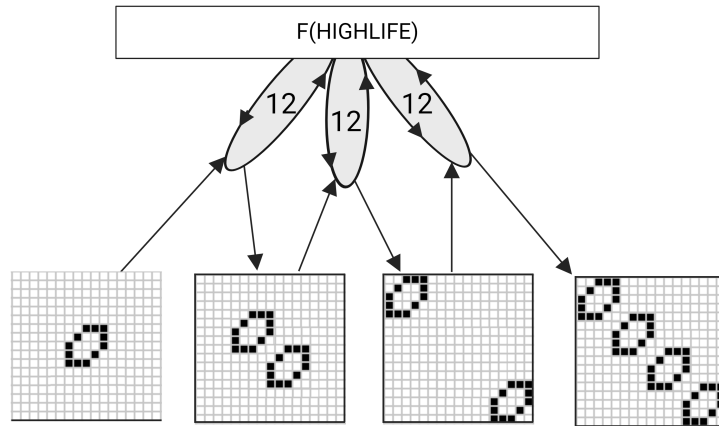

Figure 12: Grid interacts with $f(\text{HIGHLIFE})$. This structure interacts with the environment to cause multiple copies of itself to exist in the future.

The classification of an object as a constructor or replicator is not inherent to the structure. It is only defined with respect to some environment, such as $f(\text{HIGHLIFE})$ above. A replicator is a subset of constructors, as shown below.
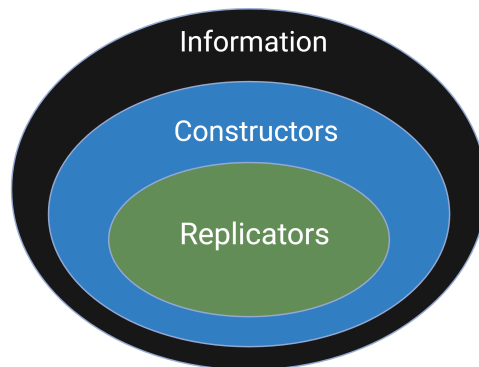

Figure 13: Replicators as subsets of constructors, which are subsets of information, in some environment.

Properties of Replicators

  – All properties of constructors

  – Embody a program for creating a copy of themselves when interacting with the environment.

2.8   Evolution

Certain interactions can cause the form of the replicator to vary. Typically, this process destroys the knowledge and ability to replicate. The 'mutated' knowledge cannot persist in interactions with the environment—knowledge is hard to come by and hard to vary. However, variation can also create new knowledge that improves a replicator's ability to propagate and replicate.

Therefore, when replicators undergo repeated cycles of imperfect copying and selection of information, they can evolve. Their knowledge becomes better optimized for whatever the environment selects for. The replicator can evolve to embody significant knowledge.
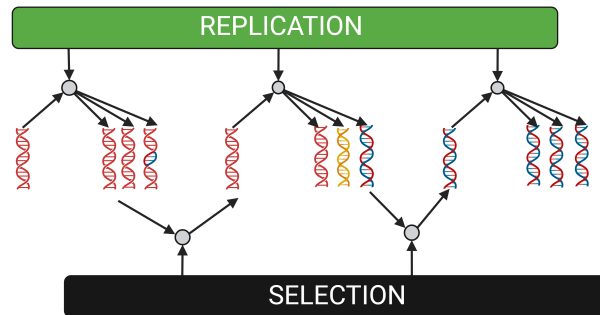

Figure 14: Repeated copying, varying, and selecting of information (the information is mutated by its environment).

Properties of Evolutionary Replicators

Evolved replicators for two functionalities:

- Embody knowledge for transforming their environment into a copy of themselves. They embody a program for their self-assembly (Von Neumann) [12].

- For interacting with the environment to propagate and gain resources for replication (typically involves creating a phenotype).

Phenotype   Any structure whose form is caused by interaction with the abstract knowledge embodied by a replicator. Dawkins' work, 'The Extended Phenotype,' shows how this extends far beyond typical intuition, where a beaver's dam is the phenotype of the beaver's gene [13].

Genes — replicators embodied in the substrate of DNA — interact with the environment to create the phenotype of a butterfly, as shown in Figure 15.
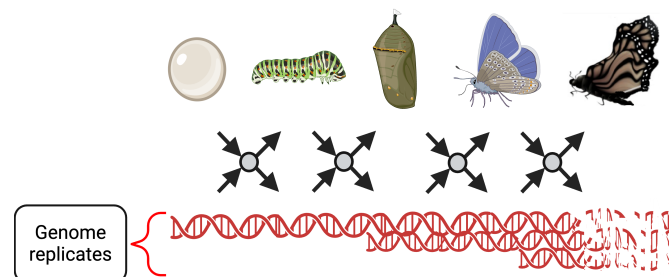

Figure 15: Genes in the genome interacting to cause the many forms of this organism.

Genetic Evolution

A gene is a single unit of heredity. Many genes exist and propagate within a single genome. Copies of a genome are created during mitosis throughout an organism's lifetime. During sexual reproduction, meiosis occurs, the genome is divided into genes and interacts with another genome to create many genomes, each with a different set of genes. This is shown by the red and blue DNA strands coming together to form many different colored genomes. These genomes then interact with their environment to create a phenotype. Selection results from how effectively this phenotype propagates and gains resources. In Fig 16, genes for darker-colored butterflies are selected for, which results in a new genome where both the pupa and butterfly have darker tones. This process of selection demonstrates how significant knowledge can result from replicator evolution.
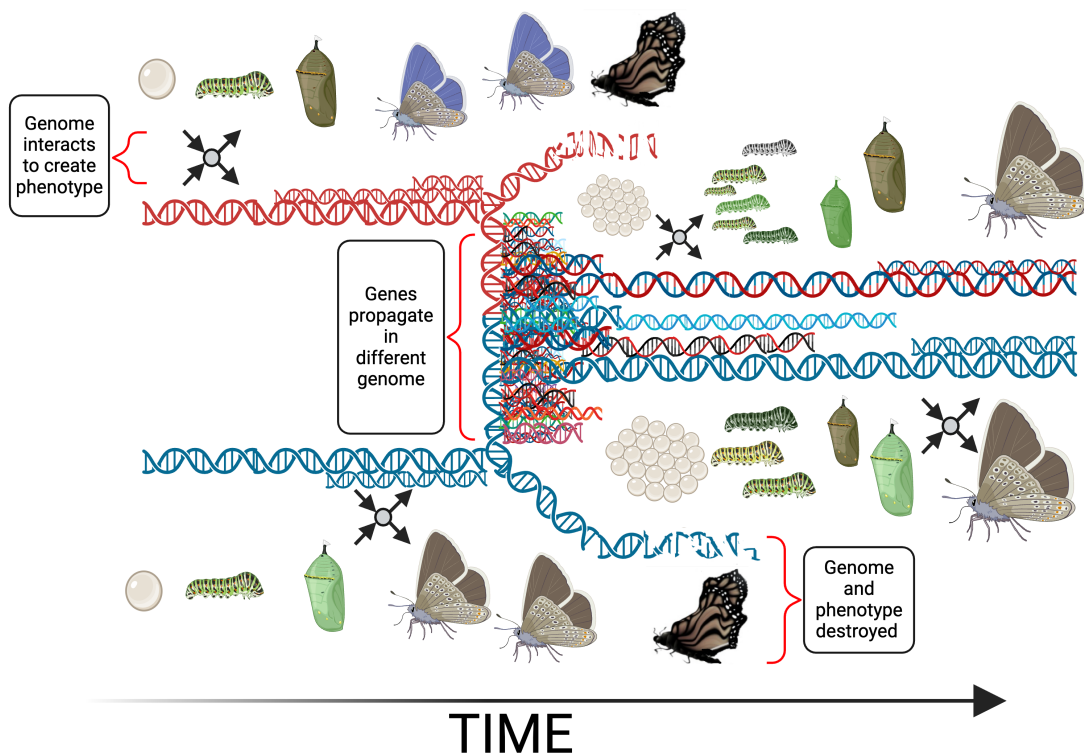

Figure 16: Successful genomes replicate throughout an organism's life. Many variants of two butterfly genomes are created during sexual reproduction. Variants are selected by their interaction with the environment. Certain genes are selected for, creating genomes that embody significant knowledge.

2.9 Universal Darwinism

Evolutionary processes exist in any information system that can copy, vary, and select. We have considered genes, where replicators are embodied by the substrate of DNA. Memes and temes are replicators embodied in the substrates of neurons and electronic processors, respectively. They are required to explain the form of reality.

Memes

Genes cause the phenotypes of brains. In brains, neurons embody information structures that can undergo repeated cycles of imperfect copying and selection of information. Therefore, neurons are a substrate for abstract replicators.

Dawkins named the replicators embodied by the information in neurons, 'memes'.

Memetic evolution results from the human capacity to create new and abstract information structures by observation and creativity. In Figure 17 below, we see the brain create a new neural structure, of the 'thumbs up' gesture, using the brain's creative capacity. When person 1 enacts this behavior, it is observed by person 2. Person 2 then has a representation of the thumbs up gesture in their neural processing. The abstract replicator, instantiated by the firing of neurons in the brain, is therefore replicated in person 2's brain. If the structure causes person 2 to enact the behavior, the meme will propagate and replicate. We now understand how memes are copied and selected.
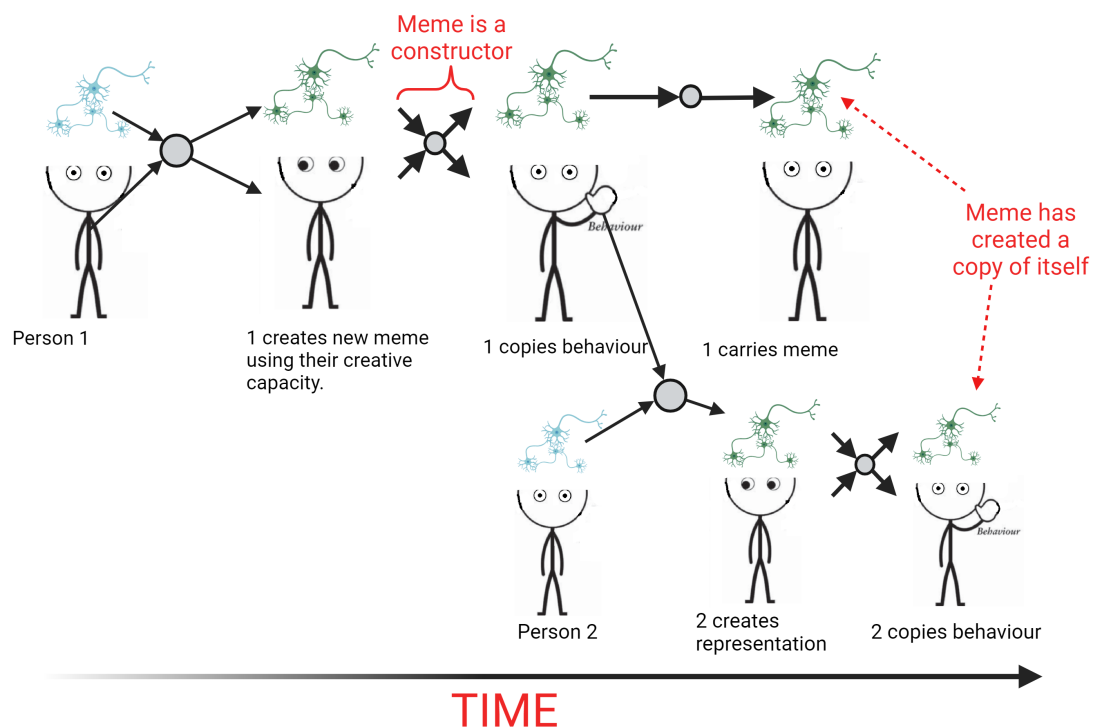

Figure 17: Person 2 copies meme from person 1.

Temes

Memetic evolution also resulted in the phenotype of tools and digital technology. The information structures embodied by artificial processing systems can undergo imperfect cycles of repeated copying and selection. Susan Blackmore termed the replicators embodied in the digital substrate 'temes'.

Game of Life rules are an example of temes. This teme has caused itself to be instantiated across many digital processing systems, as it is useful for humans. This explanation highlights the nuance in understanding temetic evolution, as it is intricately linked to memetic and genetic evolution in humans. Temes evolved to cause the phenotype of a phone's functionality, as shown in Figure 18. We now understand that temes are abstract replicators that interact with their environment to create a phenotype and cause copies of themselves to exist.
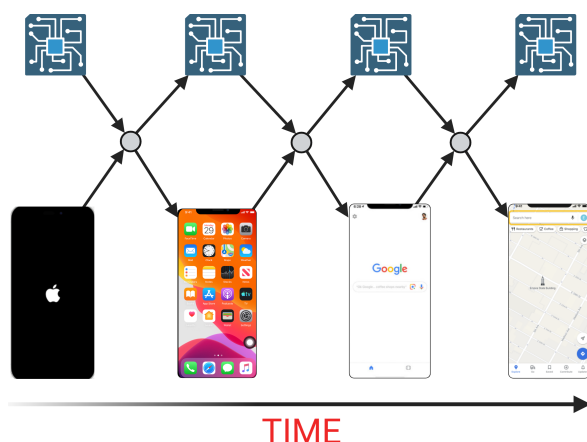

Figure 18: Temes propagate because they are beneficial to humans. Many copies of this replicator exist, instantiated by many digital processing systems.

Further properties of evolutionary replicators

Selfish

A replicator is selected by how it survives and propagates. Therefore, it embodies knowledge whose explanation for existence is the ability to propagate and replicate itself. This caused Dawkins to name his book 'The Selfish Gene' [14].

Error Correcting

Replicators contain error correction codes. The majority of mutations are disadvantageous for propagation and replication, as knowledge is hard to come by and hard to vary. It is useful for an organism to be able to return itself to its previous form after interaction that has destroyed some knowledge. Hamming codes are a type of efficient error-correcting code, created by Hamming to allow high fidelity propagation of temes [15]. ECCs (Error-Correcting Codes) are essentially some knowledge that is attached to the structure that makes it a constructor with respect to some environment. All replicators in reality embody error correction mechanisms. Examples in memetic evolution include double references to a person's gender in a sentence, such as 'He is a doctor who is respected for his work.' Another example is the degeneracy of the genetic code.

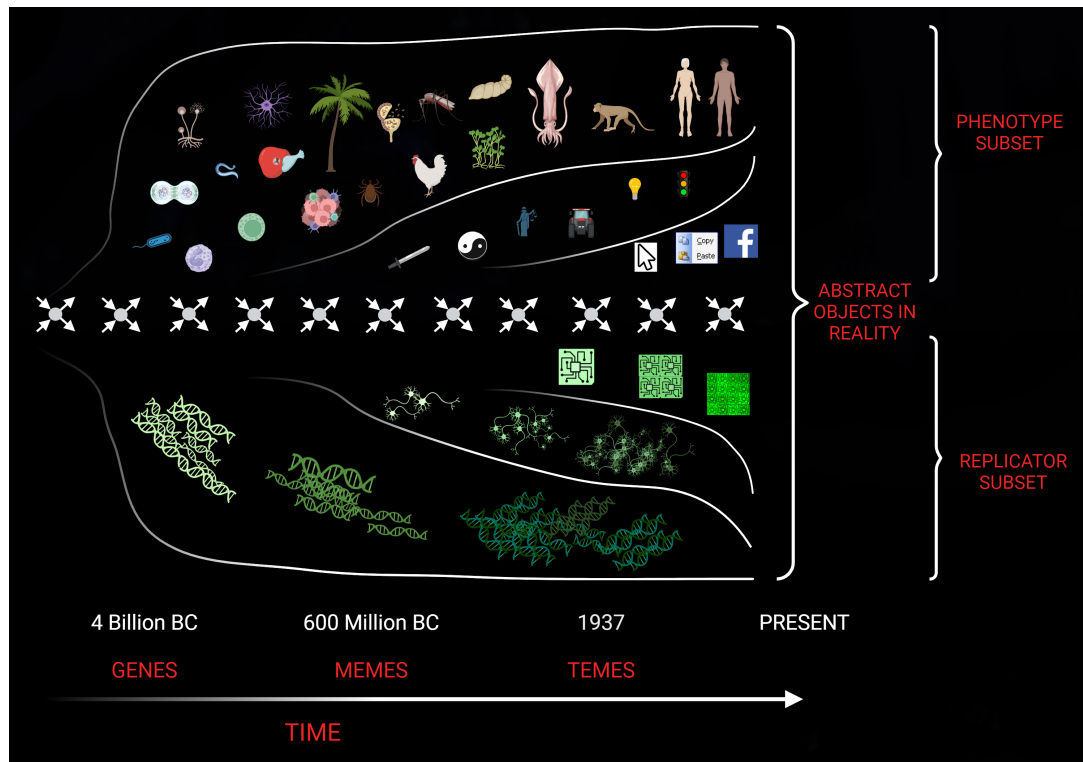## 2.10 Explanation of reality requires evolution

Figure 19: The form of many abstract objects in reality can be explained through their interaction with information replicators, which are caused by evolutionary processes.

3   Conjecture

This section presents the main conjecture of the paper - an evolutionary explanation of the fine-tuning problem.

Evolution, in some system with these two properties;

>   *- information exists,*

>   *- interaction is universal / Turing complete,*

caused the reality that existed at the Big Bang. Fundamental replicating information structures - femes - existed in this reality. As replicators, femes have propagated and replicated through time and space, and exist in current reality. The repertoire of femes is The Theory of Everything, f(ToE).

Interaction of femes and their environment can be numerically reducibly analyzed to give the dynamics of our physical theories; such as GR, QM and Newton's laws. Figure 20 is a diagram of this idea, where femes act as constructors. The diagram mirrors the explanation of numerical reducibility from Figure 6.
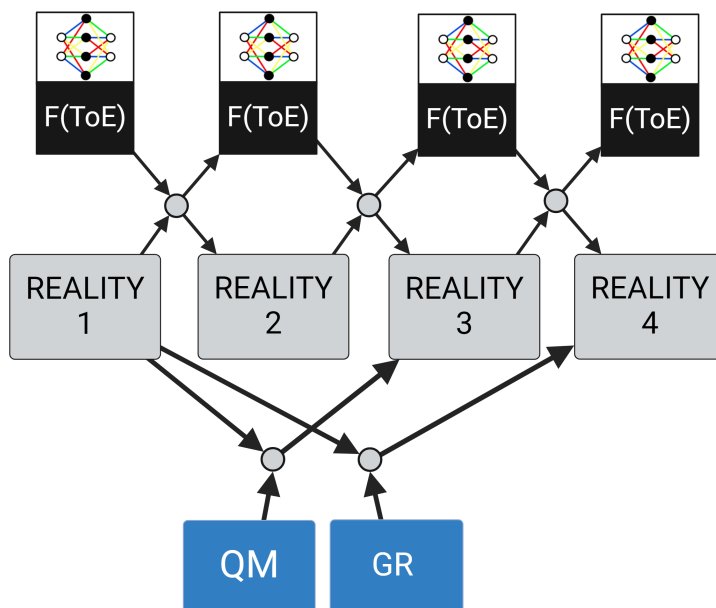

Figure 20: Reality is an information system that embodies femes, which interact to cause an environment that has numerically reducible dynamics consistent with GR and QM [1].

Four abstract replicators exist in reality

We extend the domain of Universal Darwinism to fundamental physics. The structures that exist in reality, not only all of terrestrial life and society, but fundamental physics, require explanation by interaction with replicating information structures. Four abstract replicators exist in reality - not three as previously understood. They are temes, memes, genes and femes.
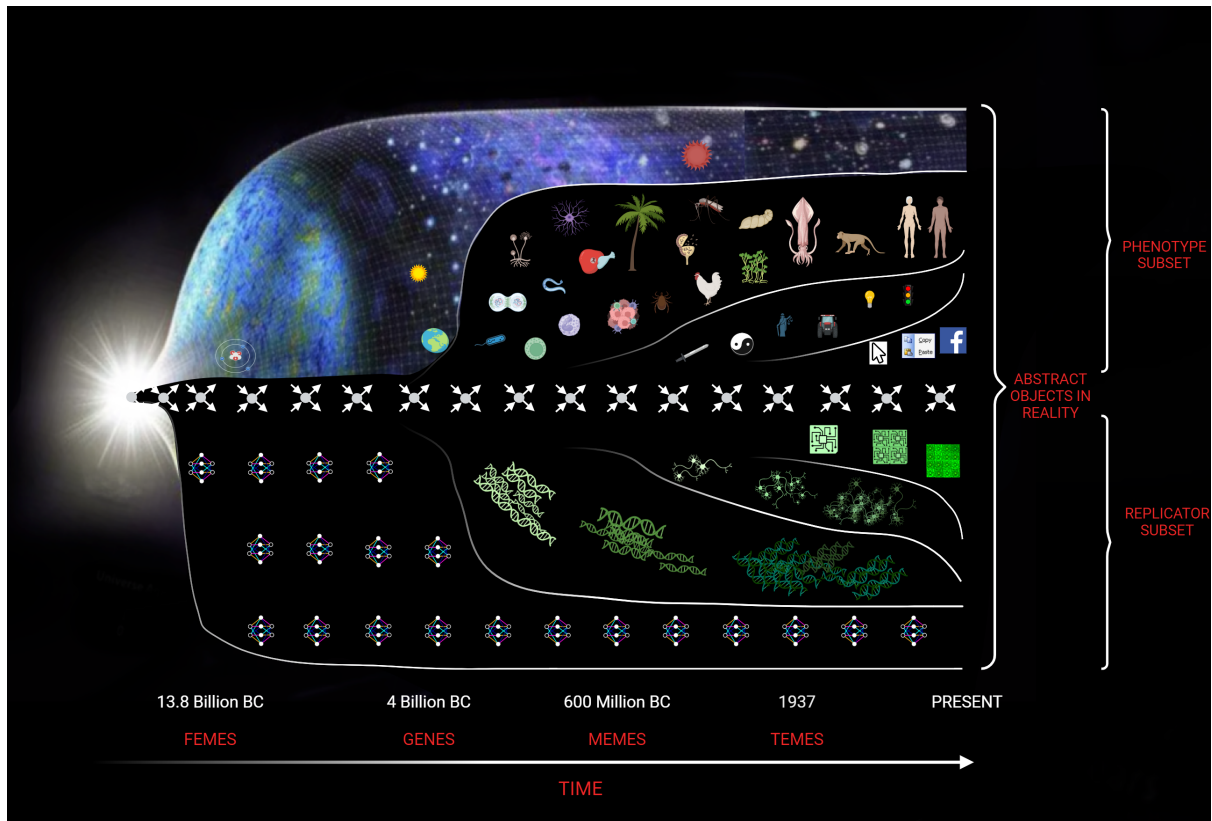

Figure 21: The four replicators and their phenotypes.

4 Predictions

This section proposes five testable predictions based on the conjecture.

Femes embody ECCs

Error correction is selected by any evolutionary system and is observed in all replicators in reality. ECCs (Error-Correcting Codes), such as Hamming codes are a highly efficient error correcting method.
There are formulations of fundamental reality that require "doubly even self-dual linear binary error-correcting block codes." One of the people who created this description, Prof. Jim Gates, has pondered the significance of this finding in relation to evolutionary theory:

> "To write equations where information gets transmitted reliably, if you're in a supersymmetrical system with this extra symmetry, that doesn't happen unless there's an error-correcting code present. So it is as if the universe says you don't really transmit information unless there's something about an error-correcting code. This to me is the craziest thing that I've ever personally encountered in my research, and it actually got me to wondering how this could come about because the only place in nature that we know about error-correcting codes is genetics, and in genetics, we think it was evolution that causes error-correcting codes to be in genomes. So does that mean that there was some kind of form of evolution acting on the mathematical laws of the physics of our universe?" [16]

Femes embody self-replication program

To constitute replicators, femes must embody a program for their self-replication, and can interact with their environment to create copies of themselves. This aligns with Von Neumann's prediction on how organisms embodying a program for their self-assembly, before the discovery of DNA.

Femes are fallible. Heat death will not occur.

All knowledge is parochial and fallible. The idea of heat death comes from assuming the eternal existence of the observed laws of physics. This work predicts that the laws of physics are replicating information structures that are fallible. Therefore, the consequences of their eternal existence are not guaranteed.

Femes are information efficient

The many-worlds interpretation is unlikely, as evolution selects for efficiency. This would be evidenced by the embodiment of efficient ECCs.

Fine-tuning results from selection of knowledge

The capacity to creates a reality conducive to complex evolutionary pathways (resulting in humans) is knowledge embodied by femes, that has been selected by evolution.

5   Further Research

This work aims to inspire new avenues of research. One example is mapping the information structure that ECCs (Error-Correcting Codes) in supersymmetry act upon.
We aim to publish two more papers:

> ***Paper 2*** - A discussion of entropy and the second law of thermodynamics from the perspective of general information dynamics. This would lend from recent work on the Second law of Info-dynamics and Assembly Theory [17, 18].

> ***Paper 3*** - A detailed exploration of the mechanisms of mutual selection between different types of replicators, and the implications for the Hard Problem of consciousness.

6 Conclusion

The conjecture in the paper is that reality embodies fundamental replicating information structures. These replicators have been named femes (fundamental-emes). This perspective changes how we understand the search for a Theory of Everything. The ToE is redefined as the set of transformations femes can cause in reality.

Inspired by constructor theory, we consider reality to follow a generalized theory of information dynamics, characterised by knowledge and its evolution through time. The process of knowledge becoming embodied by and replicating within replicators results in the form of the universe at all levels of abstraction. Universal Darwinism extends beyond genes, memes, and temes to propose the existence of femes.

There are five falsifiable predictions from this work. We hope to inspire physicists to use evolutionary ideas, like ECCs, as heuristics for guiding further research. Our aim is to encourage others to consider the value of a generalized theory of information dynamics and to further conjecture and criticism in the field.
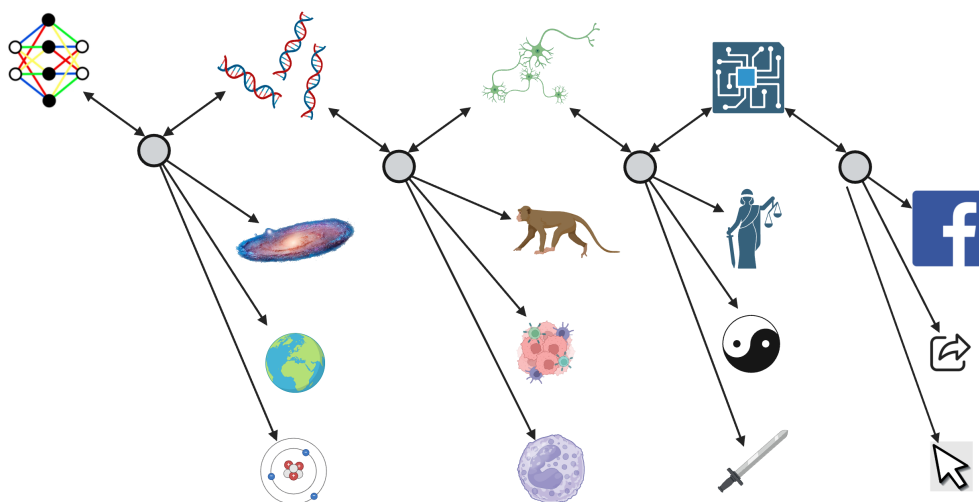

Figure 22: Replicators at different levels of abstraction.

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