Evolution of Information and the Laws of Physics

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October 26, 2023

Abstract

This paper combines insights from information theory, physics and evolutionary theory to conjecture the existence of fundamental replicators, termed 'femes'. Femes are hypothesised to cause transformations resulting in the structure and dynamics of the observable universe, classified as their phenotype.

A comprehensive background section provides the foundation for this interdisciplinary hypothesis and leads to four predictions amenable to empirical scrutiny and criticism. Designed to be understood by a multidisciplinary audience, the paper challenges and complements ideas from various domains, suggesting new directions for research.

Contents

1 Background

This section outlines key concepts in information theory, knowledge, evolution, and physics, allowing later sections to be concise. Terms in *italics* are defined in the glossary (7).

1.1 Information Theory

1.1.1 Information Interaction

Information Theory was originally formulated by Claude Shannon in his seminal 1948 paper, where he defined information in quantifiable units known as ‘bits’ [1].

Building on this foundation, Chiara Marletto, in collaboration with David Deutsch and within the framework of Constructor Theory, introduces a nuanced perspective on information through the concept of *counterfactual* potential — the potential of a structure to exist in a different, distinguishable state [2, 3]. According to this formulation, information satisfies the following criteria:

1. It is capable of adopting at least two distinguishable states, enabling transformations such as ‘flip’ or ‘not’.

2. Every state can be received or distinguished, enabling ‘copy-like’ transformations.

To elucidate this, consider two functions: f(■?) and f(□?). These functions output a square that is either black or white, symbolizing ’true’ or ’false,’ respectively. Serving as ’flip’ and ’copy’ transformations on data, they epitomize the counterfactual potential and distinguishable states of the data.

Input		f(■?)	Output	
□	→		→	■
■	→		→	□

Table 1: f(■?) or f(flip)

Input		f(□?)	Output	
□	→		→	□
■	→		→	■

Table 2: f(□?) or f(copy)

The functions, like the squares they interact with, also demonstrate counterfactual potential,a replacing f(■?) with f(□?) would result in a different outcome. This leads to the recognition that both the data and function constitute information. An information *structure* can *interact* to create a structure that is causally dependent on its form. The conception of equivalency between data and functions led to the development of lambda calculus, a foundational framework for understanding computation and universality.

1.1.2 Computation and Universality

The concept of information interacting to produce structures that are causally dependent on their form naturally extends into the domain of computation. In foundational terms as provided by Alan Turing and Alonzo Church, computation refers to a systematic procedure for solving a problem or simulating a physical process, predicated on the assumption that physical reality is computable—a subject further explored in section 1.4. Turing characterized computation as a sequence of mechanical operations executed by a Turing machine, a theoretical construct furnished with an infinite tape, a tape head, and a finite set of states for symbol manipulation according to predefined rules[4]. Church formulated the notion of computation within the framework of lambda calculus, which serves as a foundational construct for articulating computation through function abstraction and application[5].

The Church-Turing Thesis postulates that the set of functions computable by a Turing machine is identical to the set of functions that can be computed through lambda calculus[6]. Both formulations are *universal*, as they can simulate any other computational system within the same class. Universality can also be understood as the ability of a language to be arranged and reformulated in such a manner that it can express transformations between any binary input and any binary output, when the input/output is stored in an infinite information space.

In conventional computational systems, functions usually reside externally to the data they process. These functions interact with data to produce new information that is causally dependent on the form of both the function and the data. Following the interaction, the original input data is commonly deleted, and the function is retained to interact again with the newly generated output, perpetuating the system's dynamics.

In contrast, this paper examines systems where certain structures are not externally stored and reintroduced. In these systems, structures can only persist in the output if their form causes them to interact in a manner that leads to their recreation in the output. This characteristic introduces the concept of *knowledge*.

1.2 Knowledge and Constructor Theory

1.2.1 Knowledge

Knowledge, as defined by Popper and Deutsch, is information that, when physically instantiated in an appropriate *environment* (the structures a given structure interacts with), tends to cause itself to remain so (it *propagates*)[7]. Marletto describes knowledge as information capable of self-preservation[2].

This can be illustrated by a 2D binary grid structure interacting with the Game of Life function, denoted as f(GoL). The f(GoL) computes the future state of each cell based on its current state and the states of its neighboring cells[8].

Input					Output	
State	Live Neighbors				Next State	Description
□	0-2, 4-7	→	f(GoL)	→	□	Stasis
□	3	→		→	■	Birth
■	0-1, 4-7	→		→	□	Death
■	2-3	→		→	■	Survival

Table 3: Game of Life Update Function

The *glider* structure serves as an exemplar of knowledge, as it propagates when interacting with f(GoL). The structure propagates under interaction with this information (it causes itself to remain in this environment).

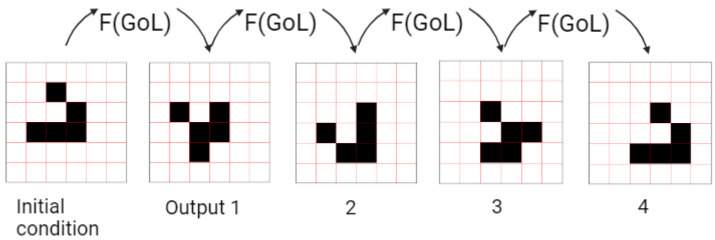

Figure 1: Glider structure interacting with f(GoL).

Knowledge is *hard to come by* and *hard to vary*. In a 3x3 grid of binary cells, there are 2^9 possible structures, yet only a limited number of these structures, such as the four orientations of a glider, two of a blinker, or one of a block, will propagate in a large empty grid.

1.2.2 Constructors

Constructors are entities that bring about transformations in their external environment without undergoing a net change themselves. Formally, a constructor C is defined as an entity that, when operating on an input X, produces an output Y such that $C(X) \to Y$ and C itself remains unchanged (exists in the output without requiring external mechanism for reintroduction): $C \to C$[9].

These constructors must embody knowledge to propagate when interacting with their environment. In contrast to functions like $f(B?)$ or $f(GoL)$, which require constant reintroduction into the system, constructors propagate autonomously. An example in physical reality is a catalyst.

In Conway's Game of Life, the 'Eater' pattern serves as an illustrative example (Figure 2). It causes a transformation that destroys a glider while undergoing no net change, embodying the knowledge needed to halt the glider.

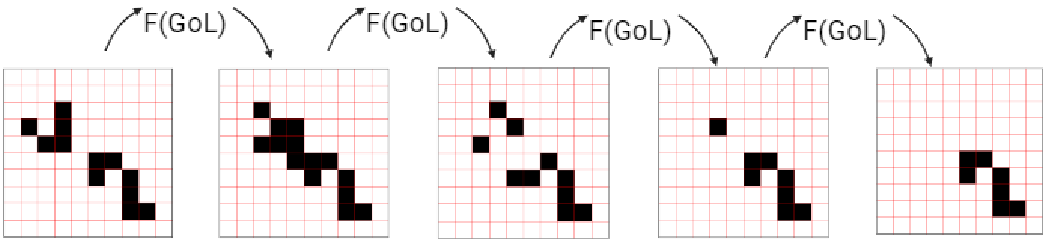

Figure 2: The Eater interacting with and stopping the Glider in Conway's Game of Life.

One of the fundamental notions in constructor theory is the delineation between possible and impossible tasks. Although a constructor's set of operations could be universal in theory, certain transformations are unattainable for any finite constructor operating within a finite information space. For example, within a 6x6 grid in the Game of Life, no constructor can generate a transformation that results in a structure occupying more than 36 cells. Such limitations mirror physical principles like the conservation of energy; no physical constructor can induce an increase in the total informational content constituting energy. This statement operates under the assumption that reality results from computation, a premise elaborated upon in section 1.4.

1.2.3 Abstraction and Reducibility

The concept of abstraction pertains to understanding the dynamics of a system through its emergent structures and their properties, rather than through the application of its fundamental rules. For instance, in Conway's Game of Life, the future state of a glider can be determined not only by applying the GoL rules to each cell but also by recognizing that the glider moves $\sqrt{2}$ grid lengths diagonally every four iterations. This is noteworthy because irrational numbers like $\sqrt{2}$ are not expressible in the binary information that constitutes the grid.

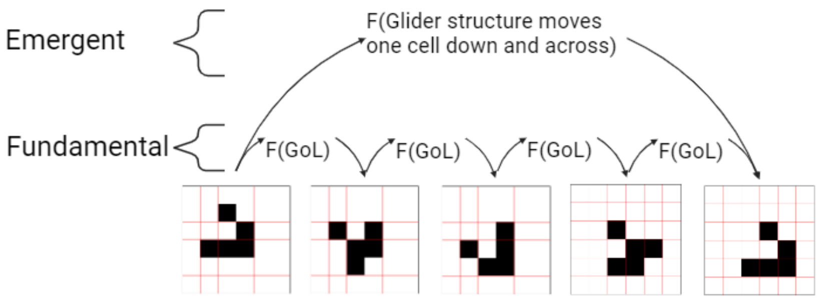

Figure 3: Abstract analysis of Glider dynamics

The potency of abstraction is further articulated by Deutsch, who cites a thought experiment by Hofstadter involving dominoes[7, 10]. These are arranged such that a specific, final domino will fall only if the initial number of input dominoes is a prime number. Here, using the fundamental physics of falling dominoes to predict the outcome would be highly complex. However, an abstract analysis can easily identify the primality of the initial number as the determining factor.

The Wolfram Physics Project introduces the term *numerically reducible* to describe systems where the future state can be more efficiently calculated through abstract identification of emergent structures and their dynamics, rather than through exhaustive computation using fundamental rules[11].

1.2.4 Infinity and Fallibility

According to Deutsch, all knowledge is both *parochial* and *fallible*. These traits are succinctly highlighted by the No Free Lunch (NFL) theorem[12], which states:

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

The theorem asserts that no algorithm A or B has universally superior performance across all problems P. If we substitute 'knowledge' for 'algorithm', we find that any knowledge k is effective only within a subset of all possible structures S, reflecting its fallibility and parochial nature.

For example, if the Game of Life (GoL) update function is varied as shown in Table 1, the glider ceases to propagate, illustrating the fallibility of this particular piece of knowledge.

Input					Output	
State	Live Neighbors				Next State	Description
□	0-2, 4, 5, 7	→	f(Varied GoL Update)	→	□	Stasis
□	3, 6	→		→	■	Birth
■	0, 2, 3, 6, 7	→		→	□	Death
■	1, 4, 5	→		→	■	Survival

Table 4: F(GoL) with varied input/output.

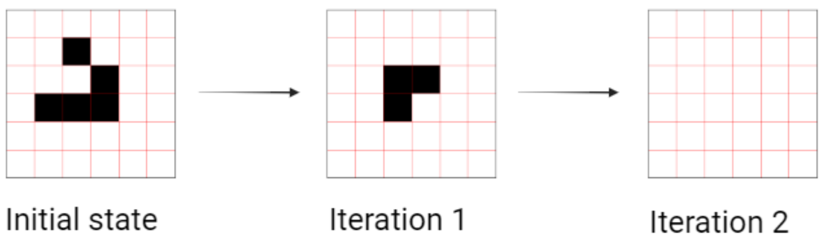

Figure 4: Illustration of a fallible glider

The parochial and fallible nature of any structure supports Deutsch's principle that *problems are inevitable*. From any given perspective, problems that could destroy the structure will inevitably be encountered. However, Deutsch also posits that *all problems are soluble*. The problem itself is fallible and subject to resolution by the unbounded space of potential knowledge, accessible through the ability to create, or more broadly, evolve solutions.

1.3 Evolutionary Theory

1.3.1 Evolutionary Systems

If knowledge is hard to come by, what causes it to exist? Marletto posits: 'It is a principle of evolutionary theory that everything with the appearance of design must have come into existence by natural selection.'[13].

Knowledge evolves in *evolutionary systems*, where there are repeated cycles of imperfect copying of information, alternating with selection. The following diagram illustrates the cyclical process causing *replication*, *variation*, and *selection*.

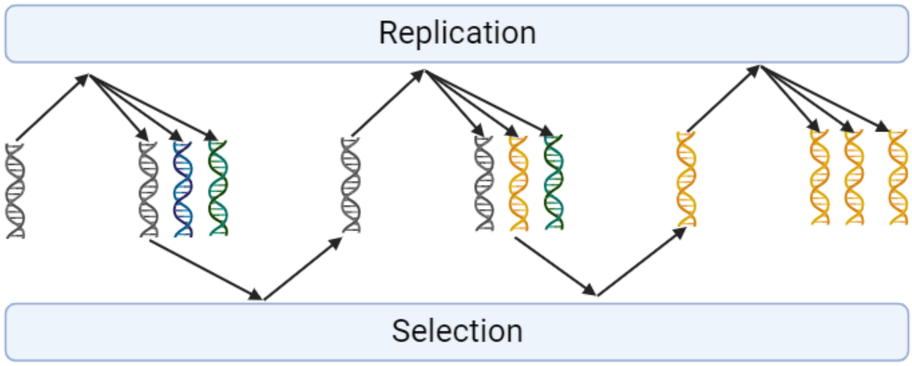

Figure 5: DNA structures undergo cycles of imperfect replication and selection, resulting in the evolution of knowledge.

These structures are selected by their propagation efficacy when interacting with their environment. Over time, mutations that improve propagation become prevalent, as they confer a replicative advantage. This iterative process causes the evolution of knowledge.

Consequently, we observe the evolution of *replicators* - constructors capable of creating copies of themselves.

1.3.2 Genetic Replicators and Phenotypes

Molecular dynamics provides a substrate for the imperfect copying and selection of abstrac structures, specifically the genetic replicators of DNA/RNA. These replicators have evolved to cause transformations that result in their own propagation and replication, making them *selfish*[14]. Any structure resulting from knowledge embodied by a replicator is termed its *phenotype*, as described by Dawkins in 'The Extended Phenotype'[15]. Genetic phenotypes can assume many forms, such as a cell wall, egg or beaver's dam.

Neo-Darwinism designates the *gene* as the fundamental replicator, not the larger *genome*. Dawkins defines a gene as 'a unit of heredity that, under the influence of an environment, directs the formation of an organism and drives its behavior'[14]. In essence, a gene is a DNA segment accounting for a specific selectable transformation. Genes are recognised by their stability and infrequent mutations, whereas genomes can manifest significant changes, especially during processes like meiosis. A genome is an ensemble of genes directing development of an organism. Each gene causes a transformation, for example, a gene may specify camouflage coloration, as shown in 6. The phenotype derived from this genetic data has a life-cycle marked by its genesis and eventual cessation, with its duration being brief relative to the gene.

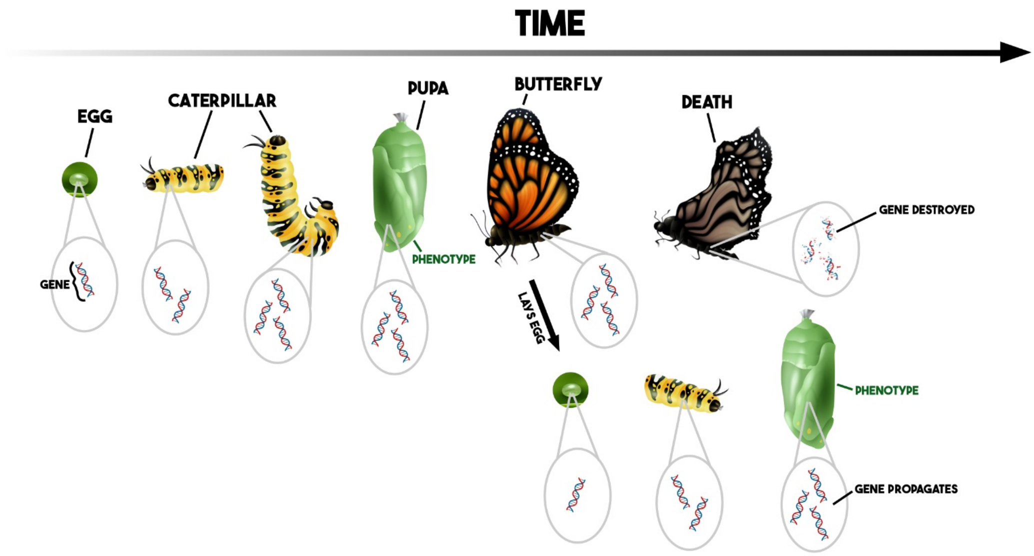

Figure 6: Propagation of the gene for camouflage coloration in the Pupa phase

Figure 6 showcases the stability of a gene influencing a lepidopteran's camouflage during its pupal stage. While the gene remains largely consistent, the phenotype is more transient. Occasional gene mutations can modify its inherent knowledge, leading to different transformations. These alterations can affect the organism's replication and propagation capacity. It is clear that genetic replicators are selected based on their transformation abilities that enhance propagation in given environments.

1.3.3 Memes and Temes

As depicted in Figure 7, gene and genome phenotypes can manifest in diverse forms, including toxins, lions, and trees. The phenotype of brains has evolved specifically to facilitate the propagation of genes. This phenotype is of particular significance because the information it embodies and transmits via neural connections establishes an abstract evolutionary system—a system where replication, mutation, and selection occur. Thus, it serves as a substrate for the formation of abstract replicators. Dawkins first introduced the concept of *memes*, replicators residing in the neural substrate, in his seminal work 'The Selfish Gene' [14].

Phenotypes arising from memes, examples of which include language and the thumbs-up gesture, can be observed in Figure 7. Analogous to how genes operate within genomes, memes function within *memplexes*—clusters of interrelated memes that often disseminate collectively. Direct physical transfer of memes from one brain to another is impractical. Rather, human *creative capacity* enables the generation of memes through interaction with existing memetic phenotypes[7]. Due to these complexities, the extension of evolutionary theory to include memetics poses nuanced challenges, which are further explored in Section 6.1.

The existence of memes has led to technological phenotypes like digital processing systems. Some of these phenotypes serve as abstract evolutionary systems, where cycles of imperfect copying and selection of abstract information occur. This leads to the evolution of another class of abstract replicators, referred to as *temes* by Blackmore [16].

Temes give rise to their own phenotypes, such as f(GoL) and Google. It should be noted that the distinction between individual temes and collections of them—termed *temeplexes*—is not rigid. These structures are instantiated in the substrate of technological information.

The central diagram below (Figure 7) encapsulates a key idea in this paper: the various complex structures observed in the world can be parsed into either replicators or phenotypes. Additionally, the relationships between abstract replicators can be understood. All replicators are selected based on their capacity to induce transformations that facilitate their own propagation and replication. These transformations, in turn, produce phenotypes, which may themselves constitute abstract evolutionary systems capable of giving rise to new abstract replicators.

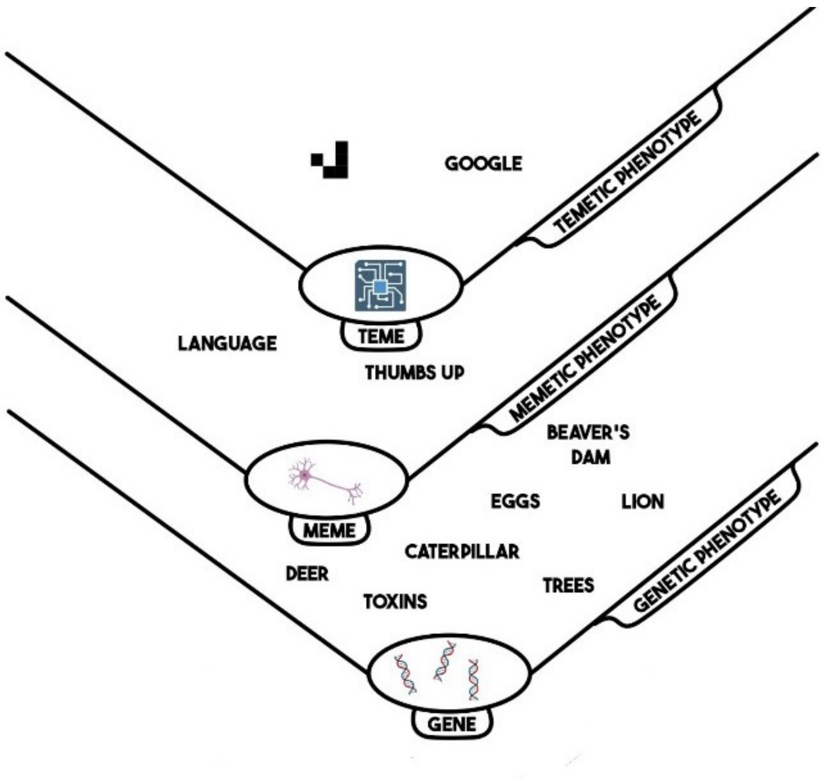

Figure 7: Causal relationships between replicators at different levels of abstraction

1.3.4 Selection

Selection among replicators is causally intricate. Replicators are favored based on their ability to propagate within environments often transformed by other replicators, leading to *mutual selection*. For example, the genes of a lion and a deer are mutually selective: a lion's successful hunt enhances its genetic propagation while hindering the deer's.

Susan Blackmore's 'meme machine' hypothesis proposes that memes exert selective pressure on genes, thereby demonstrating that selection can occur across different levels of abstraction among replicators. A subsidiary conjecture, elaborated in Section 6.1, posits that this selection is mutual. Genes can evolve a neural architecture that selects for memes conducive to their own propagation. A central premise for the predictions in this paper is that mutual selection occurs between replicators at different levels of abstraction.

Evolutionary selection's complexity is heightened when incorporating frameworks like *game theory.* Some behaviors, such as reciprocal parasite removal in birds, seem altruistic but align with selfishness within a game-theoretic context[14]. These subtleties render the construction of falsifiable predictions challenging, discussed further in Section 4.3.

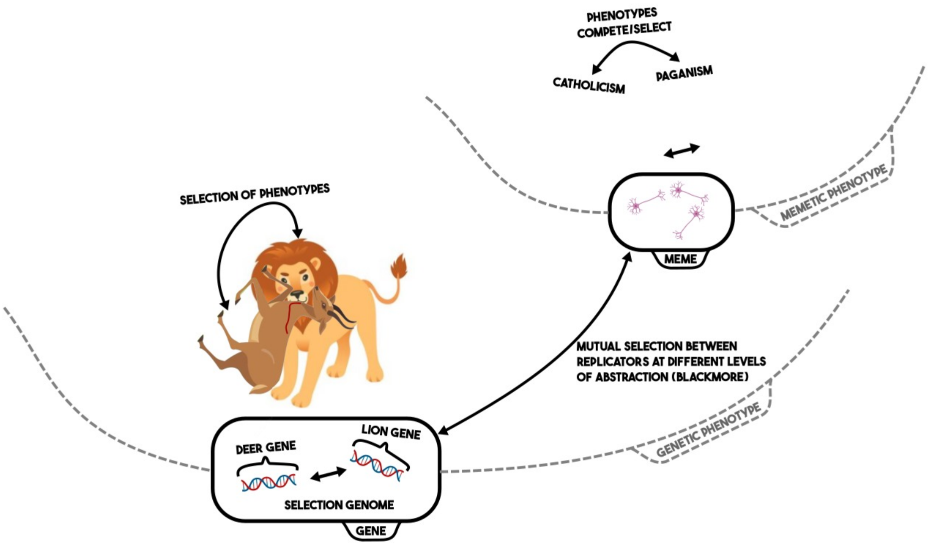

Figure 8: Mutual selection between replicators at both the same and different levels of abstraction

1.3.5 Error Correction

Error correction schemes introduce redundancy to ensure the accurate transmission of information structures. Within information theory, Shannon's foundational work elucidates the capacity for error correction in the reliable conveyance of digital information over noisy channels. This need for efficiency gave rise to mathematical formulations such as Hamming's *Error-Correcting Codes (ECCs)*[17]. These codes adeptly insert redundant bits to counteract errors like bit flips, thereby preserving the integrity of the transmitted data. In the context of temes, as discussed in Section 1.3.3, ECCs serve as knowledge generated by human creative capacity for the propagation of temes.

The principles underlying error correction are not novel but have pre-existed in both genetic and memetic replicators prior to human discovery. In genetics, error correction occurs through mechanisms like DNA proofreading and mismatch repair during synthesis [18, 19]. Analogously, in memetics, the robust creative capacity of humans facilitates the identification and propagation of memes even in noisy environments. Further details on this mechanism can be found in Section 6.1.

In summary, error correction is a ubiquitous feature in replicators, from ECCs in temes to intrinsic processes in genetic and memetic systems, serving to ensure the reliable propagation of encoded knowledge. This underscores the universal selection for efficient error correction methods in evolving replicator systems.

1.4 Physics

1.4.1 Traditional Continuous Physics

Traditional physics has predominantly relied upon continuous mathematical structures to describe natural phenomena. Fields in electromagnetism and the space-time manifold in General Relativity serve as quintessential examples. The success of calculus in these frameworks implicitly endorses the idea that nature is fundamentally continuous. However, the subsequent subsections scrutinize this assumption, examining how effective descriptions in continuous spaces do not necessarily imply that the underlying reality is itself continuous.

1.4.2 Abstract Analyses in Discrete Spaces

Building upon Section 1.2.3, f(GoL) serves as a prime example of how discrete, binary systems can exhibit emergent properties effectively described by irrational numbers, such as the velocity of a glider being $\sqrt{2}$. These irrational numbers permit a numerically reducible analysis, implying that a fundamentally discrete space can be effectively described as continuous in its emergent dynamics.

1.4.3 From Continuous to Discrete in Thermodynamics and Fluid Mechanics

Historically, thermodynamics and fluid mechanics have been portrayed using continuous mathematical frameworks [20, 21]. A more nuanced examination reveals that these seemingly continuous descriptors are in fact abstract, numerically reducible representations of fundamentally discrete underlying systems. Statistical mechanics, as elucidated by Boltzmann [22], Gibbs [23], and more recently, Jaynes [24], provides a rigorous account of how macroscopic observables such as temperature and pressure emerge from a statistical ensemble of discrete molecular interactions. Fluid dynamics is no different; although it is modeled as a continuum at macroscopic scales, it fundamentally consists of discrete molecular states. Methods like the Chapman-Enskog expansion [25, 26] offer a compelling mathematical bridge between these discrete states and continuous macrostates encapsulated by the Navier-Stokes equations.

These cases exemplify the concept that continuous mathematical representations in physics often emerge as abstract or numerically reducible formulations of fundamentally discrete systems.

1.4.4 Contemporary Physics from Computation

Both Quantum Mechanics (QM) and General Relativity (GR) are traditionally framed in continuous spaces—QM in Hilbert space and GR in the spacetime manifold. These frameworks, however, exhibit inconsistencies at the limits of their applicability. Computational physics is emerging as a reconciliatory platform, inspired in part by John Wheeler's "It from Bit" doctrine, which posits a fundamental role for information and computation [27].

Numerous theories aim to describe a fundamentally discrete spacetime, such as ur-theory [28], spacetime code [29], spin networks [30], topochronology [31], the 'It from Qubit' program [32], Gauge-Gravity Duality [33], Loop Quantum Gravity [34], and Causal Dynamic Triangulations [35].

Among these, the Wolfram Physics Project stands out, proposing that hypergraph rewriting rules can realize discrete dynamics reconcilable with both GR and QM [36, 37]. This framework suggests that continuous phenomena are emergent properties of a fundamentally discrete structure. However, this paper diverges from the Wolfram Physics Project in its interpretation of the Ruliad as the mechanism behind the existence of the hypergraph rewrite rules, as discussed in section 4.2.

1.4.5 Theory of Everything

The ultimate objective in physics is to elucidate the fundamental structure that governs the updating of information in reality — termed the *Theory of Everything* f(ToE).

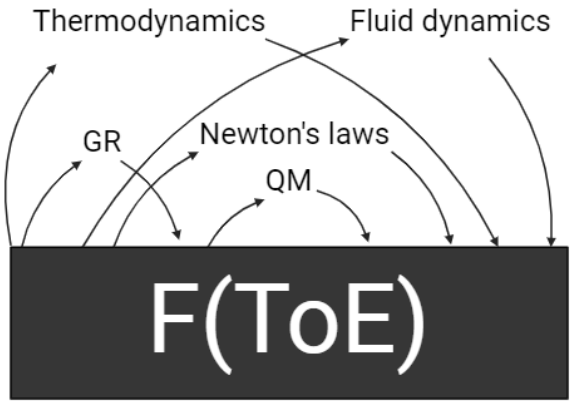

Figure 9: The function f(ToE) causes transformations to information that are susceptible to emergent analysis, described by the laws of nature.

In the Wolfram Model, the function f(ToE) is identified as the hypergraph rewrite rule, which David Deutsch terms the "Laws of Physics" [7]. This paper posits that such laws are better understood as "Laws of Nature," abstract and numerically reducible interpretations of f(ToE)'s underlying information structure.

Contrary to its nomenclature, the 'everything' in ToE can be misleading. A ToE aims to provide a comprehensive mapping at a significant level of abstraction, similar to initiatives such as the Human Genome Project. However, like the outcomes of the Human Genome Project, a ToE does not offer explanations for the numerically irreducible, emergent phenomena that result from its existence. Deutsch contends that even with a ToE, our comprehension will invariably represent only an infinitesimal subsection of possible knowledge [7].

1.4.6 Fine Tuning Paradox

A comprehensive f(ToE) would not resolve the mystery of its own existence. The extensive range of feasible laws within frameworks like the standard model, QM, or GR raises an existential enigma, one that persists even in 'landscape' theories such as Susskind's string theory landscape [38]. This conundrum, known as the *fine-tuning paradox*, questions why laws conducive to human evolution specifically exist. The anthropic perspective is considered insufficient to resolve this issue, as further elaborated in section 4.2. As Stephen Hawking aptly posed, 'what breathes fire into the equations and makes a universe for them to describe?' The following section addresses this profound query.

2 Conjecture

The central thesis of this paper is the conjecture that the fundamental mechanisms governing the observable dynamics of reality, denoted by $f(\text{ToE})$, are replicators, hereafter termed *femes* (fundamental -eme). Femes are constructors: they cause transformations and retain the capacity to cause these transformations.

Quantum Mechanics (QM) and General Relativity (GR) are posited to be numerically reducible abstractions of the information that dynamically interacts with femes. Within this framework, structures in the observable universe, such as stars and atoms, manifest as phenotypes of these transformations. Molecular dynamics emerges as a significant phenotype, as it is the substrate for the evolutionary system of genetic evolution.

The epistemological origin of the knowledge inherent in femes is attributed to evolutionary processes; the system responsible for selecting this form may therefore predate the *Big Bang*.

The paper concludes with the assertion that **every discernible structure in the universe, including the $f(\textbf{ToE})$, can be taxonomically classified either as a replicator or as a phenotype**.

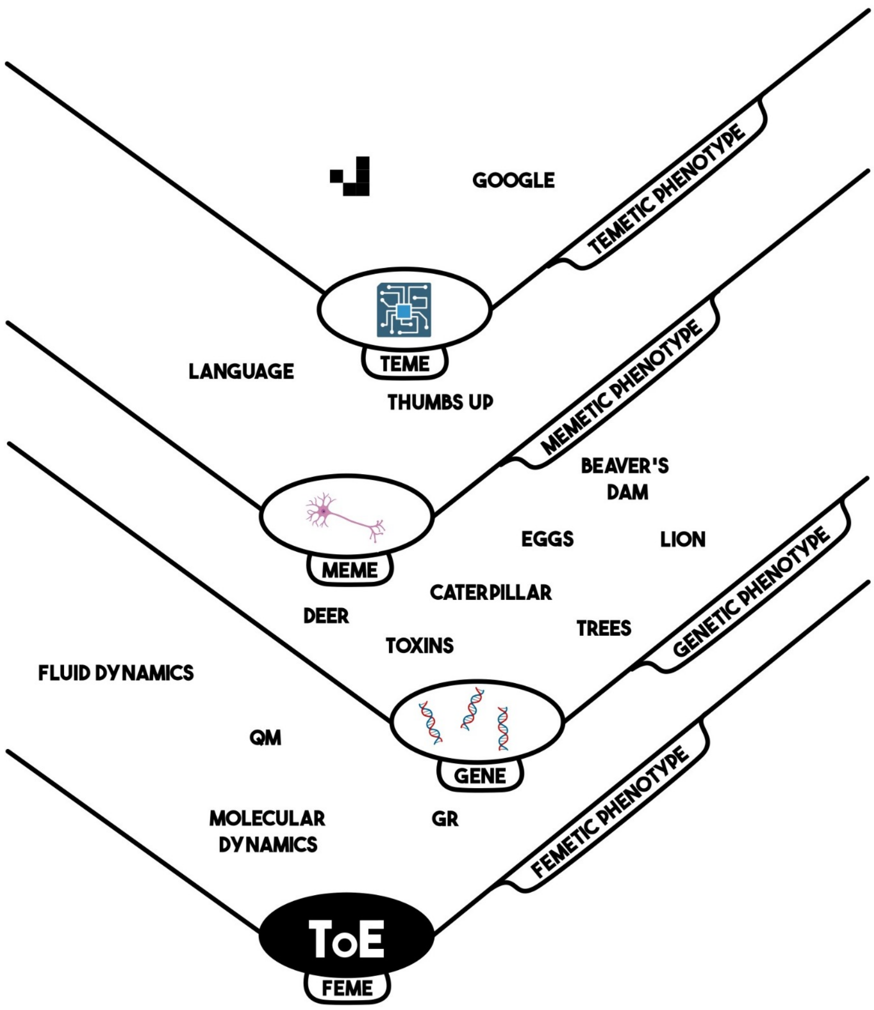

Figure 10: Diagram elucidating the interrelation between femes and emergent replicators, where femes form the substrate for this genetic replication.

3 Predictions

3.1 Knowledge of ECCs in Femes

Error-correcting schemes are selectively advantageous for ensuring the accurate propagation of replicators, as discussed in Section 1.3.5. This leads to the prediction that femes will embody some form of error correction to maintain the integrity of their embodied knowledge.

Support for this prediction arises from the work by Jim Gates et al. [39, 40], which explores the realm of supersymmetry (SUSY). Their model employs geometric objects known as Adinkras to symbolize SUSY equations via a one-dimensional representation technique referred to as 'gnomoning.' Significantly, these Adinkras contain structural foldings that align with the principles of Hamming codes - specifically, doubly even self-dual linear binary error-correcting block codes (ECCs). These ECCs are indispensable for preserving the mathematical structure inherent to SUSY. The potential ramifications of these findings have not escaped Gates, who has considered the implications vis-a-vis evolutionary theory:

> 'To write equations where information gets transmitted reliably, if you're in a super symmetrical 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?'[41]

Prediction - Femes contain ECCs.

3.2 Fallibility of Femes

In this work, femes are replicators embodying knowledge. According to constructor theory, all knowledge is fallible, therefore femes can be destroyed by interaction with evolved knowledge. Predictions resulting from the eternal existence of the laws of physics, such as *heat death* of the universe, are similarly predicted to be incorrect.

Prediction: Femes are fallible and can be destroyed upon interaction with knowledge that evolves in the future. Heat death, predicated on the eternal existence of current laws, will not occur.

3.3 Selection for Efficient Information Processing

The existence of Hamming codes in femes indicates a selection for efficient information processing. In this context, 'efficiency' refers to the minimal computational effort needed to cause a transformation. Importantly, an infinite number of functions could cause the transformations facilitated by femes, but these would vary in their computational efficiency. Given that femes are fallible, knowledge evolving in the future may provide methodologies for assessing this efficiency.

Prediction: Femes have been optimized for computational efficiency. Consequently, theories demanding extensive computational resources, such as the *Many Worlds interpretation*, are less plausible due to their immense computational requirements.

3.4 Fine Tuning and the Selection of Knowledge Promoting Feme Propagation

Femes are hypothesized to embody knowledge beyond ECCs and computational efficiency, facilitating evolutionary pathways that resist both stagnation and premature convergence. The rarity of this property is substantiated by the frequent challenges posed by many evolutionary algorithms, which tend to converge prematurely on sub-optimal solutions [42, 43]. Support for this idea, explicitly relating to the form of the laws of physics, is found in fine-tuning studies: Barrow and Tipler's work [44] discusses how minor alterations in physical laws would negate complexity; Carr's anthology [45] interrogates the rarity of life-permitting universes; and Davies' exploration [46] emphasizes the universe's fine tuning to support life.

Therefore, the ability of femes to enable non-stagnant evolutionary systems implies selection for knowledge that causes the emergence of abstract replicators. This aligns with the definition of knowledge as information that is hard to come by and hard to vary.

However, embodying properties that are both hard to come by and hard to vary does not in itself confer the status of knowledge. According to constructor theory, to be considered knowledge, a mechanism for their propagation or dissemination must exist. It is hypothesized that emergent abstract replicators function as the mechanism for femetic propagation. These replicators, facilitated by femes, propagate their embodied knowledge. It is a symbiotic relationship; the replicators and femes mutually select and propagate each other, creating a co-evolutionary cycle. The foundational concept of mutual selection and facilitated propagation of replicators across different levels of abstraction is not novel to this section. It was initially introduced and discussed in section 1.3.4 and will be considered in greater detail in section 6.1. This work aims to highlight its importance as the mechanism proposed to propagate femes and the knowledge they embody.

Prediction: Femes embody knowledge that causes evolution of abstract replicators. This knowledge is proposed to have been selected and propagated by emergent replicators. The phenomena on mutual selection and propagation of abstract replicators is discussed in section 1.3.4 and 6.1. It is predicted that the information system responsible for selecting these specific femes must have origins that predate the *Big Bang*.

4 Discussion

4.1 Cosmological Natural Selection

Lee Smolin's Cosmological Natural Selection (CNS) postulates that new universes arise within black holes, inheriting modified laws of physics from their parent universes[47]. According to this theory, the conditions within black holes serve as an environment for the replication and variation of the laws of physics. Smolin proposes the selection mechanism where universes yielding a higher number of black holes possess greater 'fitness,' thus propagating their specific laws of physics more effectively, and providing a basis for resolving the fine tuning paradox.

While 2 agrees that the form of the observable universe has been selected by evolution, it argues that Smolin's CNS misidentifies the replicator.

4.2 The Anthropic Principle and Multiverse

The *Strong Anthropic Principle (SAP)* and the *Weak Anthropic Principle (WAP)* have been well-discussed in the literature [**?**, 48]. The SAP posits that the Universe must have properties conducive to the emergence of intelligent life, while the WAP asserts that the Universe's hospitability is an observational effect because we are here to observe it [**?**]. This paper synthesizes these principles in the following manner:

We exist → Laws enabling our existence must exist (through evolutionary processes).

Although these principles have been useful for bounding the possible forms of physical laws, they are not sufficient as explanatory frameworks [49]. They don't offer insights into phenomena that might precede or exceed their scope, leaving unanswered questions about the origins or implications of fundamental laws [50].

A frequent argument for explaining these laws is the notion of an infinite multiverse, often cited in cosmological discussions [51, 52]. The concept can be encapsulated as follows:

We exist → Laws enabling our existence exist (information interaction causes evolution of knowledge in humans) → A system capable of generating these laws exists (Infinite Multiverse/Ruliad).

This paper challenges this prevailing multiverse rationale, invoking *Gödel's incompleteness theorems* [53] to argue that even an infinite multiverse would be incomplete. This stands in contrast to the *Ruliad* in the Wolfram physics project, which posits that all conceivable rules and initial conditions exist [54]. Both perspectives overlook evolutionary selection, an important phenomenon for understanding reality, which does not necessitate the existence of all conceivable rules and initial conditions [55, 56]. The idea is formalized in the revised inference:

We exist → Laws enabling our existence exist (information interaction induces knowledge evolution in humans) → A system generating these laws exists (information system that selects for the knowledge embodied by the laws of physics).

4.3 Falsifiability

Karl Popper initially labeled evolutionary theory as a 'metaphysical research program,' critiquing its purported absence of falsifiable predictions[57]. This notion has been the subject of much debate within the philosophy of science.

Falsifiability in the context of evolutionary theory diverges significantly from the laws of nature discussed earlier in this paper, which are numerically reducible analyses of the information system updated by fundamental laws. Such theories are numerically reducible and therefore computationally tractable, thus naturally amenable to prediction. In contrast, evolutionary theory, which is concerned with the propagation of information structures through time, faces considerable challenges for prediction due to the mathematical chaos inherent in our universe and the intricate interdependence of evolving structures[58]. These factors render evolutionary theory numerically irreducible and its consequences computationally intense. However, a nuanced understanding of evolutionary theory can allow for the identification of patterns within evolving systems, thereby lending itself to prediction. Notable examples include Darwin's anticipation of the elephant moth and Dick Alexander's foresight regarding the naked mole rat[59, 60].

Subsequently, Popper revised his initial critique, acknowledging that evolutionary theory could indeed generate falsifiable claims[61]. Moreover, as David Deutsch explicates, Popper's philosophy on the conjectural nature of scientific progress aligns coherently with the principles underpinning evolutionary theory[7]. Deutsch encapsulates this by stating, "Popper could just as well have written, 'We do not acquire new memes by copying them, or by inferring them inductively from observation, or by any other method of imitation of, or instruction by, the environment." The transmission of human-type memes must, in essence, be a creative act on the part of the receiver.' Creativity here is used in the sense of creative capacity, which Deutsch defines as a form of evolutionary variation.

This paper extends the domain of evolutionary theory to encompass the most foundational aspects of reality, thereby broadening its domain of explanation. Although the proposed extension may not be immediately testable, it conforms to the principles of falsifiability as articulated by Popper, namely his *tradition of criticism and conjecture*.

4.4 Future Research

4.4.1 Guiding Principle for a Theory of Everything

The degree of accuracy of predictions from current theory suggests that the f(ToE) could be *simple*, in that it may well lie within our immediate capacity to describe and understand, without considering evolutionary principles. Nonetheless, this paper contends that principles from evolutionary theory may serve as heuristics for guiding research aiming to identify the F(ToE). For example, evolutionary principles could direct further research into the nature of error-correcting codes (ECCs) and the structures they act upon.

4.4.2 Generalising Evolutionary Theory

Future research may benefit from expanding the scope of evolutionary theory beyond its traditional focus on genetics. This research aims to discern universal principles governing the behavior of diverse replicators, such as genes, memes, and temes. The objective is to identify and quantify the methods by which knowledge is selected for and propagated within these replicators. These universal principles can subsequently serve as a basis for specialized investigations into the evolutionary dynamics at various levels of abstraction, as elaborated in 6.1.

4.4.3 Assembly Theory Analysis

Another unexplored research direction is the application of Assembly Theory (AT) to the study of the form of femes and fundamental laws of physics. AT's assembly index measures object complexity by enumerating the minimal steps required for its formation. Applying this metric to the fundamental laws would yield a quantitative metric for their complexity. This would offer new perspectives on the selection functions influencing their current form and introduce an evolutionary perspective to our understanding of the laws governing the universe.

4.4.4 Evolutionary Principles for Rule Searching

Evolutionary algorithms can be employed to explore vast combinatorial search spaces to identify potential rules that share properties expected of fundamental laws. These algorithms, derived from evolutionary principles, are particularly effective for navigating immense domains such as those found in string theory. Wolfram Physics has already initiated steps to use similar selection functions in combination with evolutionary computing systems. This approach differs from directly mimicking the evolutionary process that may generate the universe; it aims to evolve rule sets that align with the existing, observable laws, for which we already have the fitness function.

5 Conclusion

This paper advances the conjecture that the observable universe is a phenotype of fundamental replicators, termed 'femes', that embody evolutionarily-selected knowledge. This knowledge is posited to have originated from interactions between information structures preceding the Big Bang.

From this hypothesis emerge four specific predictions:

1. Femes are imbued with error-correcting codes.
2. The knowledge within femes is fallible and will be supplanted upon interaction with future-evolved structures.
3. The laws of physics are optimized for computational efficiency, which challenges theories demanding extensive computational resources, such as the Many Worlds interpretation.
4. The propagation of the knowledge in femes is facilitated by emergent replicators.

Though evolutionary theory has limitations in yielding falsifiable predictions, its fundamental principles are indispensable for interpreting any complex information structure. By extending the domain of evolutionary theory into fundamental physics, this paper introduces a novel analytical framework grounded in the generalized principles of evolutionary theory.

Acknowledging the intricacies of evolutionary theory, this work argues for its application in refining our understanding of the universe. The paper encourages research into theoretical understanding of various abstract replicators and underscores the significance of such an endeavor.

While this paper introduces a hypothesis that posits a causal history for our universe, it does not address the *Something from Nothing* problem. Rather, it takes the existence and interaction of information structures as given, offering an evolutionary mechanism as the driving force behind the emergence of the laws of physics.

6 Appendix

6.1 Detailed Treatment of Memetic theory

6.1.1 Divergence from Genetic Theory

Memetic theory, first introduced by Richard Dawkins in ‘The Selfish Gene,’ posits that memes are abstract replicators existing in the substrate of neural connections. These memes, like genes, are subject to replication, mutation, and selection. Memetics is often described as the evolution of culture. It is theorised to result in the phenotype of the structures created by humans, language, gestures, religions.

It is imperative to approach memetic theory with a discerning lens, recognizing its distinctiveness from genetic theory.

While Dawkins laid the groundwork, the intricacies of memetic theory have been further explored and refined by scholars such as David Deutsch and Susan Blackmore. Deutsch, in particular, cautions against drawing simplistic parallels between biological and cultural evolution. He emphasizes that even though both domains might share an underlying theory, the mechanisms of transmission, variation, and selection diverge significantly.

6.1.2 Memetic Replication

The replication mechanism of memes differs from that of genes, as memes can’t physically transport themselves between brains (unlike the movement of genes between organisms in Figure 6). Instead, as constructors and replicators, memes cause transformations that promote their propagation and replication. The transformation results in some functional change to the behaviour of a human embodying the meme. When another individual observes this phenotype, their cognitive system can conceptualise the observed change, causing the meme to be replicated in the observer. This process leverages what Deutsch terms as the ‘creative capacity’ of humans — our ability to conceptualize and generate memes internally. These internal memes can then be further disseminated as the observer may cause the transformation that propagates the meme.

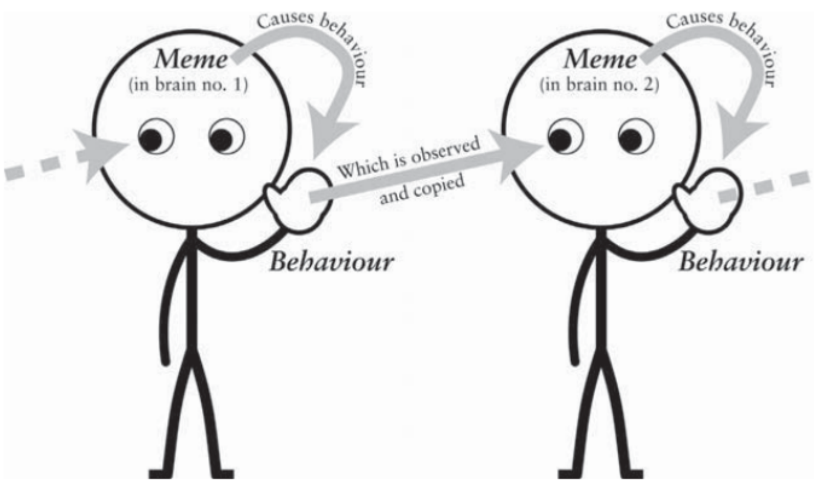

Figure 11: Deutsch’s illustration of how memes propagate

It should be noted that while a behaviour is typically defined as an action carried out by the human body, the transformation that causes replication of the meme extends to all structure in reality that causally results from the existence of the meme (in alignment with the Dawkins' concept of the extended phenotype).

Deutsch recognises that the phenotype alone can cause propagation of the meme, and can therefore be recognised as a replicator. For example, particular statues of heads found on Easter Island, called Moai, existed as physical entities long after the memes that led to their creation had vanished along with the Easter Island civilization. When they were rediscovered, new memes about their origin, significance, and construction methods were formed in the minds of the explorers and researchers, leading to the replication of these new memes (mentally and physically) in broader society. A genetic phenotype could never replicate without DNA. Therefore Deutsch states that memes have a physical and mental representation, to highlight the difference in propagation capacity of genetic and memetic phenotypes. This paper maintains that the physical meme is a phenotype, as it is the transformation caused by a replicator that has a relatively constant form.

6.1.3 Memetic Variation

Deutsch's concept of *'Creative Capacity'* underscores our innate ability to conceptualise and copy memes. He argues that this capacity initially evolved to assimilate existing knowledge. However, the same mechanism that enables copying also facilitates creation, leading to memetic variations mechanism of both imperfect copying and inherent creativity. Deutsch explains:

> 'The first (question) is why human creativity was evolutionarily advantageous at a time when there was almost no innovation. The second is how human memes can possibly be replicated, given that they have content that the recipient never observes. I think that both those puzzles have the same solution: what replicates human memes is creativity; and creativity was used, while it was evolving, to replicate memes.'

This creative capacity offers memetics a distinct advantage over genetic mutation. The brain can internally simulate and evaluate the potential outcomes of new memes, allowing for a more intelligent process of variation and selection before external expression.

> For it depends on conjecture (which is variation) and criticism (for the purpose of selecting ideas). So, somewhere inside brains, blind variations and selections are adding up to creative thought at a higher level of emergence.

6.1.4 Memes Causing the Evolution of the Big Brain

Susan Blackmore's posited the *Meme Machine* idea - memes, acting in their own selfish interest, caused the selection of genes predisposing to larger brains, thus providing a more fertile ground for meme propagation[**?**].

Deutsch delves into the co-evolution of memes and genes. He presents a counter-intuitive perspective on how memes caused selection for genes that optimize meme propagation. He explains:

> 'In early pre-human societies, there were only very simple memes – the kind that apes now have, though perhaps with a wider repertoire of copyable elementary behaviors. Those memes were about practical things like how

> to get food that was otherwise inaccessible. The value of such knowledge must have been high, so this created a ready-made niche for any adaptation that would reduce the effort required to replicate memes. Creativity was the ultimate adaptation to fill that niche. As it increased, further adaptations co-evolved, such as an increase in memory capacity (to store more memes), finer motor control, and specialized brain structures for dealing with language. As a result, the meme bandwidth (the amount of memetic information that could be passed from each generation to the next) increased too. Memes also became more complex and sophisticated. This is why and how our species evolved, and why it evolved rapidly – at first. Memes gradually came to dominate our ancestors' behavior. Meme evolution took place, and, like all evolution, this was always in the direction of greater faithfulness. This meant becoming ever more anti-rational. At some point, meme evolution achieved static societies – presumably they were tribes. Consequently, all those increases in creativity never produced streams of innovations. Innovation remained imperceptibly slow, even as the capacity for it was increasing rapidly.'

In these static societies, behavior was predominantly dictated by societal norms. Conforming to these norms was essential for survival and reproductive success.

> 'Status in such a society is reduced by transgressing people's expectations of proper behavior, and is improved by meeting them. There would have been the expectations of parents, priests, chiefs and potential mates (or whoever controlled mating in that society) – who were themselves conforming to the wishes and expectations of the society at large. Those people's opinions would determine one's ability to eat, thrive and reproduce, and hence the fate of one's genes. And that is how primitive, static societies, which contained pitifully little knowledge and existed only by suppressing innovation, constituted environments that strongly favoured the evolution of an ever greater ability to innovate.'

Blackmore's proposition, which Deutsch agrees with, is that the human brain's primary evolutionary purpose was meme replication.

> 'Blackmore's "meme machine" idea, that human brains evolved in order to replicate memes, must be true. The reason it must be true is that, whatever had set off the evolution of any of those attributes, creativity would have had to evolve as well. For no human-level mental achievements would be possible without human-type (explanatory) memes, and the laws of epistemology dictate that no such memes are possible without creativity. On the face of it, creativity cannot have been useful during the evolution of humans, because knowledge was growing much too slowly for the more creative individuals to have had any selective advantage. This is a puzzle. A second puzzle is: how can complex memes even exist, given that brains have no mechanism to download them from other brains? Complex memes do not mandate specific bodily actions, but rules. We can see the actions, but not the rules, so how do we replicate them? We replicate them by creativity. That solves both problems, for replicating memes unchanged is the function for which creativity evolved. And that is why our species exists.'

In conclusion, the intertwined evolution of memes and genes, as detailed by Deutsch and Blackmore, provides profound insights into the complex interplay between our cognitive and biological evolution. However, while their ideas explain the result of memes causing selection of genes, neither considerations give explicit detail on the genetic selection of memes. This is the topic of the following sub-conjecture - a memetic selection mechanism results from the evolution of genes that could selfishly select on memes that caused their propagation. The evolved mechanism is posited to be a neural architecture that generates the conscious experience.

6.1.5 Memetic Selection (sub-conjecture)

In his exploration of memetic theory, Deutsch subtly yet consistently touches upon the mechanisms underpinning meme selection. He doesn't rigorously define a mechanism but gives explanations that appear to implicitly align with the sub-conjecture:

> 'the selection mechanism of memes in the form of jokes is how 'amusing' they are perceived to be.'
>
> 'each meme competes with rival versions of itself across the population, perhaps by containing the knowledge for some useful function.'
>
> 'To be transferred, a meme needs to seem useful. 'Useful' in this context does not necessarily mean functionally useful: it refers to any property that can make people want to adopt an idea and enact it, such as being interesting, funny, elegant, easily remembered, morally right and so on.'
>
> 'In such an environment, people are continually being faced with unpredictable problems and opportunities. Hence their needs and wishes are changing unpredictably too.'

The genetic selection of memes conjecture considers the co-evolutionary dynamics between genes and memes, as previously outlined and referenced in 1.3.4. We postulate that genes have evolved mechanisms to select memes that enhance their propagation. This necessitates a neural architecture capable of associating and selecting abstract memes based on their contribution to genetic propagation.

A pressing question emerges: how does this architecture bridge the abstract domain of memes with the tangible domain of gene propagation? We suggest that the concept of *utility*, expressed as emotional experiences, serves this function[62, 63]. As Deutsch notes, memes propagate and replicate based on their resonance, humor, or alignment with human desires. Drawing inspiration from Hume, these desires are framed as utility evaluations, and are transmitted by their influence on emotional experience of the human.

The *hard problem* of consciousness presents a challenge: understanding why certain neural processes lead to subjective experiences[64]. Within our framework, the hard problem results from the requirement for systems selecting on memes to be processed simultaneously with functional processes (the *easy problem*), possesses a neural architecture that integrates these evaluations, culminating in the generation of conscious experience.

Invoking Descartes's dualism, the distinction between the mind and the body parallels our theme of abstraction. The mind, adept at engaging with abstract memes, contrasts with the tangible, physical realm. Through the perspective of co-evolution, we infer that the complexities of consciousness have evolved as a necessity, propelled by the selfish propagation of abstract replicators.

To illustrate, one can consider *memeplexes* like religious beliefs. These systems, which often advocate activities such as marriage and societal cohesion, directly support genetic propagation. Such memeplexes have evolved and a propagated by individuals because they interacting with the neural structure evolved by genes that assesses their utility in relation to genetic propagation.

6.1.6 Relation to primary conjecture and predictions

The proposed selection mechanism for memes is integral to the primary conjecture and the predictions set forth in this paper.

To fully grasp memetic selection, it's essential to consider the causal influences of genetic replicators at different abstraction levels. This causal framework underscores the selection dynamics among abstract replicators.

Similarly, femes assume their form due to their causal relationships with other abstract replicators, mutually influencing each other's evolution and propagation. This concept of mutual selection between abstract replicators interconnects the sub-conjecture with the paper's main conjecture and predictions .

7 Glossary

Information: Originally introduced by Claude Shannon, it's the study of quantifying and communicating information.

Distinguishable: Output different

Counterfactual (Marletto): A property of information structures that allows them to yield varied outputs upon interaction.

Structure: Information embodied in non- arbitrary, well defined form, with counterfactual properties.

Interaction: Information structures causing the existence another stature, causally dependent on their form, interact.

Function: (transformation/ operation). Interacts with some information to create output. Is similar to a catalyst in that it is typically retained after interaction.

Data: Conceptually similar to data. Structure that can typically be input and output from a function. Normally it is acted on or transformed

Lambda Calculus: Formulation of computation where functions and data are recognised as equivalent.

Computation / System: Is the system if information structures interact. Computation in the interaction of information, where the output of interaction is typically retained and significant for the future development of the system.

Universality: (Turing complete) Property of computational systems if they are sufficiently complex to simulate any well defined transformation between sets of information. Turing Machine is example of a universal machine, therefore a Turing machine can simulate the operation of any universal machine, and any universal machine can simulate any Turing machine.

Knowledge (Deutsch): Evolutionarily shaped information with an ability for self-replication or retention.

Environment: Set of structures that are interacted to be interacted with.

Knowledge (Marletto): Information capable of self-preservation.

Propagate: A structure propagates if it exists after interaction with some other structure.

Glider: Structure in a CA that has 4 orientations, each of which cause itself to propagate when interacting with the f(GoL).

Constructor: (abstract catalyst) A structure causing transformation without undergoing any net change. It retaining the ability to do cause a transformation again.

Transformation: (Task) A process that alters the state or composition of a structure, leading to a new set of properties or functionalities.

Hard to Vary: A characteristic of a theory or explanation that cannot be easily modified without compromising its explanatory power or internal coherence.

Hard to come by: A description of knowledge or information that is difficult to acquire, often because it is deeply embedded in complex systems or requires intricate methods for extraction.

Abstraction: Ability to define structures in a system and their properties, such that the system can be understood at a level of abstraction other than the fundamental updates

Fundamental: Most basic level of abstraction, that must exist in order for emergent properties to exist.

Emergent: results from fundamental level

Numerically reducible system: A computational system is reducible if the future state of the system can be calculated by means other that computing the fundamental updates. Glider in the GoL is an example.

Parochial: Any knowledge facilitates propagation upon interaction with a subset of the infinite set of possible structures.

Fallible: Any knowledge would fail to propagate upon interaction with infinitely many unique functions.

Problems are inevitable: From the perspective of any structure, interaction with structures that can destroy the structure will inevitably be encountered.

Problems are soluble: Any structure that can be encountered in itself fallible, and evolution can always create structures that will avoid destruction upon interaction with the problem.

Evolution: A dynamic process that governs the transformation of structures over time, characterized by replication, mutation, and selection.

Evolutionary system: System with repeated cycles of imperfect copying of information, alternating with selection.

Replicate: Exact or approximate copy of a given structure, thereby perpetuating its constituent structure and knowledge.

Mutate: The introduction of variations in a structure, which may result in novel functionality

Selection: A mechanism by which certain structures are preferentially retained or discarded based on their efficacy or fitness in a given environment, resulting to an accumulation of beneficial traits over time (knowledge).

Replicator: An entity that passes on its structure largely intact in successive replications.

Selfish: All replicators are selected only by their capacity for self-propagation.

Phenotype: Any transformation caused by the information embodied by a replicator.

Gene: (Dawkins) A stretch of DNA that influences an organism's form, function, or behavior in such a way that it affects the chances of that particular stretch being replicated in future generations.

Genome: The collection of genes contained in an organism.

Meme: Abstract structure existing in the substrate of connections between neurons, that causes some transformation that impacts the probability of propagation and replication.

Memeplex: A cohesive collection of memes that tend to be propagated together. Analogous to a genome in genetics, a memeplex represents a complex of ideas, beliefs, or practices that reinforce each other and are often spread as a unit.

Teme: A unit of technological information, residing in artifacts, capable of self-replication, mutation, and selection.

-eme: The '-eme' suffix usually connotes some kind of fundamental, indivisible unit within a given system. For example, in linguistics, a "phoneme" is the smallest unit of sound that can distinguish one word from another. Used here to denote replicators that generate some system of phenotypes.

Mutual: (bi-directional) the propagation capacity of all structures involved in an interaction is impacted.

Game Theory: Paradigm required to understand complexity of evolutionary interaction. Study of how structures interact/ compete/ transact over time.

Theory of Everything (ToE):

Feme: The replicator hypothesized to generate observable reality, which results from evolution. The term uses the '-eme' suffix used in 'gene', 'meme' and 'teme' to denote replicator.

Fine Tuning Problem: Question of why the universe accommodates life, given that this property is rare.

Heat Death: A hypothesis predicting the universe's ultimate state as one devoid of thermodynamic free energy, rendering it incapable of sustaining entropy-increasing processes. [65]

Many Worlds Interpretation: Bifurcations in causal history of QM means that each possible history and future was and will be instantiated by information.

Big Bang: Instantiation of the laws and initial conditions that resulted in the observable universe.

Godel's incompleteness theorems: A pair of theorems in mathematical logic asserting that within any sufficiently rich and consistent language, there exist statements that cannot be proven true or false.

Tradition of Conjecture and Criticism: Popper's doctrine that testable laws should be testable.

Simple: Accessing some knowledge is simple if it is well within the capability of an evolutionary system to create this knowledge. Neil Turok states that the laws of physics are exceptionally simple.

Something from nothing paradox: Why does information exist and interact?

Meme Machine hypothesis: The proposition that the human brain has evolved as a mechanism for generating, processing, and propagating memes.

Utility: A measure of the perceived value or benefit of an action, choice, or object. In economics and decision theory, utility represents an individual's satisfaction or preference. In the context of memetics, utility evaluates the desirability or resonance of a meme within an individual or group.

The Easy Problem: The challenge of understanding the brain's functional processes and mechanisms.

The Hard Problem: The question of how and why the brain's processes lead to subjective consciousness.

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