Why is There Life?

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James C. Thornton

ABSTRACT

Research on the origin of life focuses on how life evolved. An intriguing second-order question is: Why is there life? Exploring the forces, mechanisms, and physical laws (and their interactions) that define the creation of animate matter is both theoretically interesting and useful to understanding the biological and philosophical nature of life. Defining the key factors ("effectors") behind the creation of life opens a fertile field of possibilities, yet incompletely explored. The discussion of these effectors helps to advance our understanding of why there is life by elucidating the motive force behind the creation and evolution of animate and inanimate complex matter throughout the universe. The results of these effectors, working in conjunction with the electromagnetic force, are summarized. Similarities in the evolution of animate and inanimate complex matter are explored to explain how animate matter relates to the universe. Characteristics considered unique to life (creation, metabolism, growth, reproduction, evolution, 'self' and the logic of the metabolic machinery, together "autopoiesis") are explained employing an expanded definition of complexity applicable to both sides of the animate-inanimate divide.

1. INTRODUCTION

The traditional approach to life's origin focuses on how life emerged and evolved, and where and when the transition to animate matter occurred. Advances in our understanding of the biochemistry of life's origins continue in laboratories around the world [1,2]. The thermodynamic consistency of increasing organic complexity and proven or plausible scenarios for a host of prebiotic constructions leading to advancing organic complexity, have been proposed [3,4]. Theories have been suggested to explain the creation of advanced prebiotic chemistry transitioning to life [5]. Such theories are categorized as either bottom-up or top-down [6]. An extensive literature has developed over the past century for the bottom-up school, which builds on the gradualism of increasing organic complexity [7]. The equally plausible top-down approach, conversely, envisions the sudden emergence of animate matter upon attainment of critical levels of certain interacting molecules resulting in autopoietic systems [8]. Crucially all theories share the *recognition complexity advances*. Although there is no certainty the level organic complexification reached on the prebiotic earth, organic complexity advanced markedly in transformation to animate matter. This tendency of increasing complexity frames the discussion below.

2. WHY IS THERE LIFE?

An additional question to the inventory of how, when, and where life arose is: Why is there life? The motive force behind why advancing complexity should occur remains uncertain, but when elucidated will add greatly to our understanding of life. Comprehending why life must evolve from inanimate matter by exploring the nature of the forces, mechanisms, and possible laws impacting the creation of life will enhance our understanding of what life is in the broadest context. As we continue to develop our knowledge of how life may have arose and what life is, why there should be life is becoming a focus of attention.

However, uncertainties persist whether the 'why' question can be answered. Parenthetically, William Schopf wonders if the 'why' question should remain within the realm of philosophy and religion [9]. Christian de Duve ponders whether we will ever succeed in explaining the origin of life naturally or whether this phenomenon is naturally explainable before affirming it will be discovered within the natural world. However, he claims as long as the problem is not solved, the tendency to invoke 'something else' will subsist [10].

Is there something unique in the transition to animate matter or, is this 'something else' suggested by de Duve, simply a natural progression of advancing complexity as has been suggested by others [11,12,13]. The overriding question is whether this 'something else' is a deterministic or contingent process [14]. Stuart Kaufman opines: "Somehow, in some as yet mysterious process, the organic molecular diversity of this spinning globe has taken energy . . . and cooked itself up from simple atoms and molecules to the complex organic molecules we find today . . ." noting, " . . .we now seek to understand the wellsprings of this stunning molecular diversity" [15]. However, complexity has advanced in the universe and understanding why this is so is inextricably partnered to the question: Why is there life?

What forces, mechanisms, and possible laws direct the creation of life? Advancing complexity, inanimate or animate, is evident throughout the universe usually requiring input of energy into these dynamic kinetic non-equilibrium systems

[16]. Defining the complexification of matter in broad terms will be shown to facilitate our understanding of life's unique characteristics.

3. DIFFERENTIATING ANIMATE FROM INANIMATE MATTER: COMPLEXITY AND TELEONOMY

The most apparent contrast between animate and inanimate matter is animate matter's vastly advanced complexity [17]. A second contrast is the drive and tenacity of animate matter to persist [18]. It is this unique aspect of life, i.e., its drive to persist, which causes the greatest philosophical conundrum, raising the question of whether life has purpose.

Why did life (a highly complex system of organic matter) evolve from less complex inanimate organic matter and why does animate matter demonstrate a tenacity to persist, grow, reproduce, and evolve? At the pinnacle of evolution this resilience to persist is manifest in our desire to procreate and avoid death, the strongest motives of which we are cognizant. To grasp the essence of this 'force' or its purposeful nature consider the DNA repair enzyme Uracil DNA glycosylase whose sole 'purpose' is to stride along DNA. When the repair enzyme encounters a uracil base pair mismatch its 'job' is to remove the wrong base allowing insertion of the correct matching base by additional enzymes [19]. The 'purpose' is to maintain the informational integrity of DNA so a mutation won't pass to the next generation during meiosis and mitosis, and metabolism won't be impaired through faulty transcription. From the perspective of the biochemistry involved, this singular example of metabolism is easily explained. Yet, behind this process one still ponders the 'why' question. Why does this repair enzyme go about its business day after day? In other words, what is the driving force behind this example of metabolism and by extension all life? To phrase the question in a non-teleonomic, non- biological way: What facets of the physical universe drive the advancement and maintenance of complexity regardless of the nature of the system? The drive to create and advance the complexity of animate matter will be explained by first defining the forces and mechanisms pushing the creation and advancement of complexity in general. Secondly, life's unique characteristics: metabolism, growth, reproduction, and evolution will be explained employing a broad definition of what it means to complexify matter, where, for example, one component of complexification provides a foundation for understanding the tenacity to persist, and other component definitions provide the underpinning for all life's unique purposeful characteristics (growth, reproduction, and evolution). It will be shown the same forces and mechanisms for the creation and advancement of animate complexity equally apply to inanimate matter and the same broad definition of complexification correspondingly explains the advancement of complexity of the inanimate realm. In summary, it will be evident advancing and maintaining complexity, in and of itself, must be a central component to understanding life's creation and purposeful nature.

4. DEFINING COMPLEXITY

Addy Prose states complexity is not readily defined, and attempts over the years to quantify the concept within the biological context have not proven too successful [20]. He acknowledges the nature of biological complexification as *the* nut that needs to be cracked and in answering the 'why' question: "The goal and challenge is to ascertain rules, if such rules exist, that govern processes of complexification" [21]. Christian de Duve uses an intuitive meaning, complexity is that which is: the opposite of simple [22].

Herein, a definition of complexification of animate and inanimate matter describes advancing molecular complexity as the creation of molecules with increasing numbers of atoms and their arrangements, and increasing systems chemistry complexity by increasing numbers of interactions between molecules and increasing numbers of chemical pathways and their interactions. However, advancing complexity must be understood in its fullest sense to explain the variety, degree, and amount of matter as it complexifies. The following qualifiers define fully inanimate and animate complexification. As with inanimate complexification, the complete list of descriptors of animate complexification will be realized at a level allowed by the physical environment. These descriptors can have variable representation and different hierarchical relationships within any given inanimate or biological system, based on that system's relation to its environment.

Advancing complexity includes maximizing the net amount of complex matter; maximizing the variety of molecules and their interactions; maximizing the degree or the level of complexity of molecules and their interactions; and, importantly, maintaining complexity at a level permitted by the environment where both thermodynamic and kinetic control of reactions occur.

5. IS THERE TELEONOMY?

This last descriptor, i.e., maintaining complexity at a level permitted by the environment, when applied to animate matter serves to connect complexification to teleonomy. For at the most fundamental level, life's purpose is to persist. Yet, for purpose to be fully manifested all the descriptors of complexification will play some part. The tenacity to persist appears as a driving force in both the creation and maintenance of life. This apparent force has been recognized since antiquity, and continues to pervade even the most recent literature [23]. Henri Bergson proposed élan vital to explain the vigor and drive of animate matter to survive and grow in his book *Creative Evolution* in 1907 [24]. As recently as 2000, Stuart Kaufman recognized the " . . . core of life remains shrouded from view," stating: "But what makes a cell alive is still not clear to us. The center is still mysterious" [25]. Life's apparent vital force and purposeful nature, which persists within each living cell even as atoms and molecules forming the cell are impermanent, remains a black box for theoretical and evolutionary biologists, and raises the question why this peculiar transition of matter occurs [26].

Addy Pross questions how purpose could emerge from an objective universe? How can any natural organization of matter act on its own behalf? He asks: “What then is the nature and source of life’s apparent élan vital, that teleonomic character already evident in a bacterial cell?”[27] Peter Corning proposes the most distinctive property of life is its dynamic goal directedness. Living systems actively pursue survival and reproduction, and they employ an immense variety of different survival strategies in an immense number of different environments. He also notes this internal teleonomy remains something of a “black box” for evolutionary biology, and it is still not understood how this goal directedness in life originated and evolved [28]. Geoffrey Zubay declares living systems are designed to thrive and replicate in their environment noting several hundred to several thousand reactions proceed simultaneously in the confines of a living cell for the purpose of maintenance and propagation of the system [29].

If there is purpose to life, and accepting advancing and maintaining complexity is necessary to defining purpose, its definition must be distilled to satisfactorily encompass advancing and maintaining complexity on both sides of the animate divide, i.e., to explain why in the preanimate environment the Neo-Darwinian complexification of organic molecules and rudimentary systems chemistry occurred, and why further complexification of organic molecules and their interactions through advanced systems chemistry occurred in the transition to animate matter.

When considering life’s purposeful nature, the maintenance of complexity is a paramount characteristic. However, a complete inventory of the components of advancing complexity was presented, and to fully invest life’s purposeful nature, the full catalogue must be applied to animate matter including advancing the variety and degree of complexity, and maximizing the net amount of complex matter. When applied, these component definitions of complexification explain the full spectrum of life’s unique characteristics and purposeful nature.

6. EXPLORING WHY THERE IS LIFE

Addy Pross gives considerable attention to why there is life. He asks the question in the sense of identifying the driving force [30,31]. Pross differentiates the historical question of how life arose from the ahistorical question of why life arose, making the distinction to identify the driving force behind the process as opposed to defining the exact historical events of life’s creation [32]. He believes that the general answer to the ‘why’ question will need to be formulated in terms of a general law, independent of the specifics [33]. He also believes answering the ahistorical question will help to understand the historical question [34]. He further notes, “ . . . the real challenge is to decipher the ahistorical principle behind the emergence of life, i.e., to understand why matter of any kind would tend to complexify in the biological direction . . . and it is this ahistorical question, independent of time and space, which lies at the heart of the origin of life problem” [35]. A mechanism is required for the process of complexification far away from equilibrium systems that adhere to the Second Law, he notes [36,37].

Stuart Kaufman proposes, “ . . . when a sufficiently diverse mix of molecules accumulates somewhere, the chance that an autocatalytic system - a self-maintaining and self-reproducing metabolism - will spring forth becomes a near certainty” [38].

Eric Chaisson has shown as each type of ordered system, from galaxies, stars, planets, and then life, becomes more complex, its normalized energy budget increases [39,40]. This process, he suggests, governed the emergence and maturity of our Galaxy, our star, our planet, and ourselves [41].

Stanley Salthe believes form, [i.e., life], is capable of initiating convective flows that move energy from gradients towards the sink more effectively than can haphazard conduction, like diffusion. He concludes the Second Law is the final cause of all form, or that form has teleological meaning [42]. Thus, the purpose of life and why we are here is to propel entropy production through an advanced complex system of organic chemistry [43].

Understanding why there is life is approached from many avenues, as evident from these examples. Why there should be life is considered employing a tiered energy flow metric to explain the existence of increasingly complex inanimate and animate matter; a teleonomic description where animate matter exists to enhance entropy production; or a description relying on inherent qualities of the system, i.e., the manifestation of autocatalysis, catalytic closure, systems chemistry, and autopoiesis which provide a sufficient description of why life exists.

7. WHAT IS LIFE?

What is Life?

	Plasma Membrane	Metabolism	Reproduction (Growth)	Evolution
Eric Chaisson	+	+		
Steen Rasmussen	+	+	+	+
Erwin Shrodinger	+	+		
Manfred Eigen	+	+	+	+
Stuart Kaufman	+	+	?	?
Freeman Dyson	+	+		+
Tibor Ganti	+	+	+/ -	+
Geoffrey Zubay	?	+	+	+
Pier Luigi Luisi	+	+	+	+
Humberto Maturana & Francisco Varela	+	+	+	?
John Oro	+	+	+	+
Clifford Grobstein	+	+	+	?

The essential components of life for individual organisms are two, one physical and one functional: a cellular structure that metabolizes or in non-biological terms, complex matter that is self-contained and persists within its environment. However, for all components of advancing complexity defined above to be fully realized - maximizing the volume, variety, and level of complex matter - requires, at the population or species level, not only metabolism, but also growth, reproduction, and evolution.

8. A DIFFERENT PERSPECTIVE ON LIFE

The difficulty characterizing life partly reflects the inability to subdue our biocentric prejudices. Perhaps disengaging from our anthrocentric world-view and subduing our biocentric prejudices further insight can be achieved into why we are here and how animate matter relates to the universe. From this view, commonalities of advancing complexity to either side of the animate divide are seen to be synonymous. Employing a broad definition of complexity assists in understanding life's unique characteristics and teleonomic nature.

9. CREATING ELEMENTS

When elements and subatomic particles interact the variety and complexity of elemental matter advances. Gravity drives this process by increasing the concentration (proximity) and energy of elemental matter within the core of stars [44,45,46]. In a supernova explosion the initial implosion through gravitational collapse occurs driving electrons into protons creating neutrons. The shock wave of the enormous increase in neutrons created increases the density of matter outside the core allowing heavier elements beyond polonium with short half-lives, to undergo the S neutron capture process [47]. The shock wave of a supernova explosion acts as a surrogate to gravity greatly increasing pressures and densities of matter, further driving elemental evolution [48]. Of the four forces of nature gravity drives the creation of elements within stars by maximizing proximity and kinetic energy of matter.

10. CREATION OF MOLECULES

While creation of the elements depends on gravity and its surrogate mechanism within stars, the electromagnetic force is compulsory for chemical reactions and acts as the fundamental energy source [49]. However, since reactions cannot occur without contact between atoms or molecules, mechanisms enhancing proximity are critical to the chemistry of molecular constructions. Gravity is the prime mechanism for bringing reactants into apposition. Surrogates of gravity include kinetic factors such as the solar wind, shock waves, the temperature of ISM clouds and electrostatic attraction between ionic species and neutral species through Van der Waal forces [50].

Sun Kwok and Pascale Ehrenfreund believe chemical pathways that could not proceed in the gas phase were possible with surface catalysts on solid interstellar grains leading to the formation of complex molecules and that surface catalysis on interstellar grains enables molecular formation and chemical pathways that cannot proceed in the gas phase [51,52]. Grains act as a strong surrogate of gravity.

11. EARTH'S PREANIMATE ORGANIC EVOLUTION

For complexity to advance beyond that achieved in the ISM an environment absent the low densities and destructive effects of the ISM was required. Earth provided this environment greatly enhancing proximity of reactants through gravity's influence on solid, liquid, and gaseous matter at the earth's surface. However, proximity was further augmented through surrogates of gravity, including evaporation, freezing, and concentrating reactants on clay surfaces and alkaline vents. Through concentrating mechanisms organic abiotic reactions will form amino acids [53] and the nitrogen bases: adenine, guanine, cytosine and uracil [54]. The prebiotic synthesis of sugars is a multistep process requiring a catalyst, which can be a clay mineral [55]. Nucleosides are formed by condensation of a sugar and a nitrogen base by evaporation to dryness [56]. Creating polymers of amino acids and nucleotides is not energetically favored so energy is required in the form of activating groups or with condensing agents [57].

Once the ceiling of complexification of the abiotic organic environment was achieved complexification of organic matter halted. A new, more tolerable environment to foster, concentrate, and protect complex organic matter was needed. The creation of the cytoplasmic environment by the thermodynamically favored construction of the plasma membrane allowed this transformation.

12. CREATION OF ANIMATE MATTER

A feature of animate matter is the ability to establish a far greater capacity to concentrate complex molecules and elements within a limited cytoplasmic environment and subcompartmental spaces, an idea originally proposed by Alexander Oparin [58]. Stuart Kaufman's theory for the creation of life depends on a defined cellular environment that concentrates a variety of molecules. He proposes, " . . . when a collection of chemicals contain enough different kinds of molecules (some of which will act as enzymes), a metabolism will crystallize from the broth", further proposing, " . . . the rate of chemical reactions depends on how rapidly the reacting molecular species encounter one another - and that depends on how high the concentrations are . . . matter must reach a certain level of complexity in order to spring into life" and that, " . . . such self organization may have made the emergence of life well-nigh inevitable" [59].

Translated to non-biological terms, a new level of complexity in net volume, variety, and degree of complex matter and complexification of their interactions will be attained and maintained based on the dynamic kinetic equilibrium of the system, just as occurs with non-organic and preanimate organic complexification. This strategy comports with all the components of complexification proposed: complexity will increase in volume, variety, and degree, and be maintained.

The logic of the metabolic machinery (autopoiesis) is to promote and maximize the component definitions of complexification, and is driven forward by the forces and mechanisms proposed. It is difficult and peculiar to accept, without attaching a cognitive sentient element that echelons of advancing logistical strategies exist and then evolve as organic matter crosses the animate divide. The classic signaling networks we associate with autopoiesis were most certainly present in simpler forms before animate matter. Therefore, the enigma of autopoiesis is best understood by abandoning any biocentric, anthrocentric, or cognitive overlay, accepting logical processes exist in isolation of cognition. Distilling these processes to their most fundamental functional level, it is clear they exist simply to promote advancement of the components of complexity by the forces and mechanisms proposed.

13. CONCLUSIONS

To sum up, this extended abstract has explored why life exists by focusing on how the evolution of life is crucially related to the notion of complexity. By employing a comprehensive definition of complexity and describing the forces and mechanisms promoting complexification, this paper has shown how complexification affects both sides of the animate-inanimate divide.

The interaction of two forces of nature with matter generally serves to increase the complexity of matter. Specifically, elemental complexity advances when subjected to gravity and molecular complexity increases when subjected to gravity and the electromagnetic force. The degree, variety, and amount of complexity created and maintained in an environment reflects a balance between this mechanism and the tendency of complex systems that are far from thermodynamic equilibrium and are under dynamic kinetic control to deteriorate. Separation from the environment through the creation of the plasma membrane is essential to augment the gravitational effect of increasing the concentration and proximity of highly complex organic molecules and to allow advancement of systems chemistry and autopoiesis. Importantly, the cell imposes the anthrocentric concept of ‘self’. Life’s ‘purpose’ becomes a manifestation of optimizing all the components of complexification of the animate system, in particular its maintenance. When these defining qualities fail animate matter will not persist.

Nevertheless, the creation, maintenance, and maximization of the net amount, variety, and degree of complex matter occur similarly with both inanimate and animate matter. When disengaging from our bio-centric view, it is evident the creation and maintenance and maximization of the variety, degree, and net amount of animate matter, is identical to the inexorable process of increasing complexity of all matter under the above-discussed mechanism. When considered from an a-biological perspective animate matter is simply an extremely complex and concentrated system of organic matter, which is maintained (metabolizes), can increase in net volume (reproduces and grows), and can increase in the degree and variety of complexity (evolves) by remaining isolated from its higher entropy environment.

Animate matter can occur under favorable conditions anywhere in the universe. When gravity, its surrogates (the concentrating effect of the plasma membrane and enzymes), and the electromagnetic force (essential for chemistry and often the energy source) cause the creation, maintenance, growth, and advancement of the complexity of an animate system, we call these processes creation, metabolism, growth, reproduction, and evolution. These processes appear purposeful because they are manifest through compartmentalization within a plasma membrane so as to showcase the emergent quality we call ‘self’. But this merely reflects our anthrocentric prejudice.

The purpose, if one chooses to use this concept, of the interaction of gravity and the electromagnetic force with matter, reduced to its most fundamental level and applicable to animate and inanimate matter alike, is to create, maintain, grow, and evolve a complex system through maximization of the volume, degree, and variety of matter of that system.

When considering the phenomenon of life through the mechanism proposed, the questions: ‘Why is there life?’ the anthrocentric question: ‘Why are we here?’ and the mystery of life become less opaque. The historical transition to animate matter will likely have numerous commonalities throughout the universe due to the dynamical nature of carbon, and because the essential component in creating life - the creation of the cellular environment - is thermodynamically favored. Although there is no élan vital in the creation and maintenance of life in the classic sense, gravity, its surrogates, and the electromagnetic force drive this process. Under appropriate environmental circumstances life becomes a probable outcome whenever and wherever matter is perpetually subjected to these forces.

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