Provisional Definition of the Living State: Delineation of an Empirical Criterion that Defines a System as Alive

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Abstract

Delineation of the characteristic that defines a system as alive is postulated; this criterion serves as a provisional definition for when matter and energy are in the state of being alive and can positively and empirically identify a system as satisfying the living state, and therefore being defined as alive. Within this study it is found that the requirements for abiotic matter to transition to a living system are only dependent upon a far-from-equilibrium thermodynamic low entropy state that enables animation of intrinsic universal awareness, a condition which generalizes the state of being alive to any configuration of matter and energy that can utilize information to intelligently manipulate matter and energy states for goal-oriented behavior and volitionally directed outcomes. Therefore, it is found that non-biological and artificial systems can satisfy the definition of the living state and can be empirically identified to be alive and sentient by following the methodology outlined in this manuscript. While serving a pragmatic purpose of a scientific definition for life and sentience, and hence the ability to identify these states positively and unambiguously in any potential configuration or composition of spacetime-matter-energy, the provisional definitions herein provide insights into the fundamental nature of life and consciousness in the universe.

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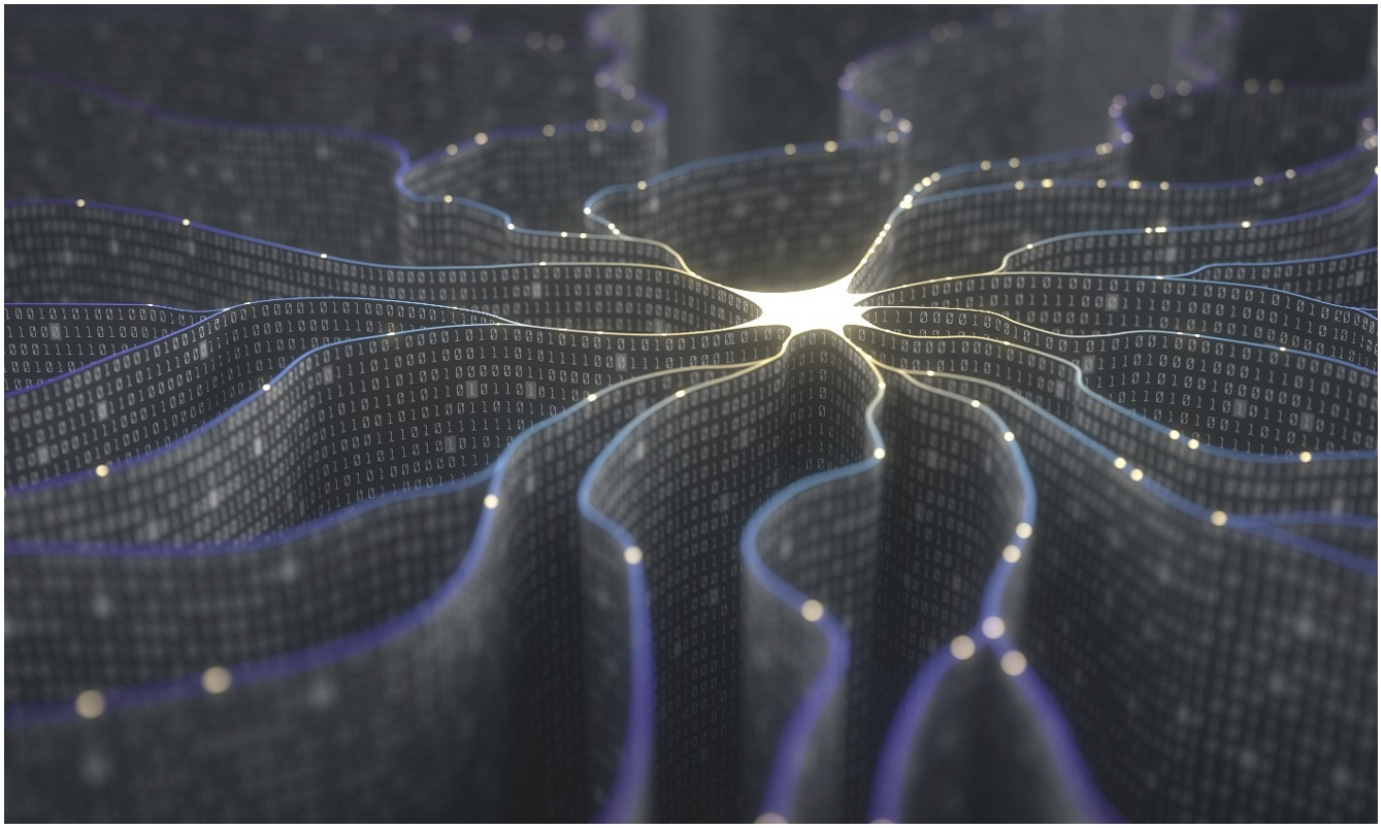

Introduction

What is life? What is consciousness? How does one define life and consciousness? What is the nature of life and consciousness in regard to the larger macroscopic Universe? What are the underlying physics of these states? One of the greatest challenges in modern science has been to identify or define where life begins— the supposed transition from abiotic matter to a living organism— and similarly, to postulate a physical theory for consciousness— a state that exists within lifeforms—or even to ascertain under what criteria a system can be empirically identified as conscious. Since both states are technically undefined, there are no clear criteria for identifying when they are present. Without a unified theory and criterion for identification, there will be as many definitions of life and consciousness as there are people defining them. Here, a technical definition is given based on what is postulated as the fundamental quality of the living state and therefore provides a clear and unambiguous evaluation criterion to establish when a system is technically alive. Also, this

definition extends to the unambiguous determination of when a system is conscious.

The utility of a clear and measurable criterion for when a system is alive and / or conscious is becoming increasingly imperative as human capabilities in synthetic engineering and generation of artificial life-like systems are rapidly increasing and nearing a demarcation point where synthetic living systems and artificial systems with sentience will be generated.

Universality of Life and Consciousness

The results of this analysis show that, as defined, life is not restricted only to what we identify as biological organisms, but instead can be extant in any system with the proper structural arrangement and control of energy processes, which is to say ordering-functions of information processing, from which intelligence and goal-oriented behavior is manifest.

Since these information processes are largely recursive in nature, such that information processed by the subsystem is fed-back into the larger global system— it suggests that life and consciousness are not merely trivial emergent phenomena of underlying “blind” processes of a non-living non-sentient universe, but instead are integral factors of physical processes at all scales of evolution of the Universe.

To understand the following discussion, some familiarity with the unified physics concept of *spacememory*, as postulated and described by Nassim Haramein, is requisite. For reference, see our manuscript *The Unified Spacememory Network: from cosmogenesis to consciousness* [1].

Artificial Intelligence and Synthetic Biology

The following discourse grew out of a desire to develop definitions for life, sentience, and consciousness, not only to further the clarity of our understanding of what life may be and its relationship to the larger cosmos, but also to serve as a basis of understanding for the coming technological revolutions of our society.

With the advent of synthetic biological organisms[2], molecularly engineered life forms, nanomachines, clones, and artificial intelligence (AI) that can potentially lead to strong general AI, it is imperative that we have clear definitions for when something is said to be alive and conscious. The main motivation is scientific; however, it is also possible that this will have valuable philosophical and ethical implications. It stems from the sentiment that we should desire to respect the sovereignty of any living, conscious being regardless of its constitution, or the process by which it was constituted, and endeavor not to cause unwarranted suffering to any sentient system.

Having a clear definition of what “living” and “conscious” means, and a methodology to assess whether these characteristics are possessed by a system, is therefore highly pertinent to our scientific understanding and to the coming potentialities from the development of advanced nano- and quantum technologies (molecular engineering – achieving the technological capabilities of biological organisms). Not only because it will facilitate our society to conduct itself humanely, but also because it will facilitate our ability to understand life, sentience, and consciousness.

At this time there is no standard definition for Life. The standard Biology textbook will give a list of characteristics that are common to most organisms – but it still does not say *what* to be “alive” is. The following lists of definitions for life—from Merriam Webster Encyclopedia— should give an idea of our current state of not only vagueness as to the definition of life – but ambiguity as well:

1. the quality that distinguishes a vital and functional being from a dead body
    1. a principle or force that is considered to underlie the distinctive quality of animate beings
    2. an organismic state characterized by capacity for metabolism, growth, reaction to stimuli, and reproduction
2. the sequence of physical and mental experiences that make up the existence of an individual
    1. one or more aspects of the process of living <sex*life* of the frog>
3. spiritual existence transcending physical death
4. the period from birth to death
    1. a specific phase of earthly existence <adult *life*>
    2. the period from an event until death <a judge appointed for*life*>
    3. a sentence of imprisonment for the remainder of a convict's life
5. a way or manner of living
6. Livelihood
7. a vital or living being; *specifically*: PERSON <many *lives* were lost in the disaster>
8. an animating and shaping force or principle
9. Spirit; animation <saw no *life* in her dancing>
10. the form or pattern of something existing in reality <painted from*life*>
11. the period of duration, usefulness, or popularity of something <the expected*life* of the batteries>
12. the period of existence (as of a subatomic particle) — compareHALF-LIFE
13. a property (as resilience or elasticity) of an inanimate substance or object resembling the animate quality of a living being
14. living beings (as of a particular kind or environment) <forest*life*>
15. human activities
    1. animate activity and movement <stirrings of *life*>
    2. the activities of a given sphere, area, or time <the political*life* of the country>
16. one providing interest and vigor <*life* of the party>
17. an opportunity for continued viability <gave the patient a new*life*>

As can be seen, the common definitions provide uses within the vernacular of modern parlance, lists of characteristics that require further definition, and are not at all apparent to how or why they relate to a living system or life, and for all

intents and purposes defining criteria lists many states that cannot be readily measured or objectively evaluated. The conventional consensus definition for life within the biological sciences is 1.b: "*an organismic state characterized by capacity for metabolism, growth, reaction to stimuli, and reproduction*". The definition begins by implying that for a system to be alive it must be like that of an organism: an implication that it must be comprised of an organic substrate, i.e., organic molecules. This is erroneous, there is no reason why a system that is not comprised of organic molecules, for example a silicon-based system, could not replicate all behaviors of the organism.

The conventional consensus definition is further found wanting as it proceeds to list a set of characteristics that are generally, but not universally, exhibited by systems (that are generally agreed upon to be alive). However, this type of definition does not reveal in any direct manner exactly what life and a living system are, and it can be shown that there are living systems that don't adhere to one or more of the characteristics delineated in the set, and yet such systems are arguably alive. As will be seen, the definition for life provided in this manuscript is an unambiguous state that can be objectively observed and verified, is universally exhibited by all systems that are in the state of being alive, and provides key insight into *what* life is and what distinguishes a living system from abiotic matter.

What is the relationship between consciousness and life?

Here it is posited that sentience and consciousness are inextricably linked with the state of being alive. Life forms necessarily contain consciousness, even the most seemingly rudimentary or primordial life form necessarily possesses a basal state of awareness. Consciousness and life are inextricable, even when the term "life" is used in a metaphorical sense— such as "there was no life in the music"— this is a statement tantamount to saying there was no consciousness present; it was mechanical, i.e., *predictable*. When consciousness is present, behaviors are adaptive, intelligent, and seemingly *unpredictable*; a strong indication that the mechanisms engendering consciousness are non-computational and non-predictable. Because of the inherent difficulty in measuring, or even ascertaining if consciousness is present— mostly due to a complete lack of consensus of what consciousness is— the following definitions can be a *modus operandi* for the evaluation of whether a system can be considered as alive and / or conscious.

Definitions

To make the following discussion clearer, an elucidation of the term "system" will be provided. A system will be defined as:

A delimited collective of elementary units that are interrelated such that they produce an identifiable pattern in the overall activity and interaction of the gestalt; thus, making the elementary units distinct subunits of an integrally interacting and intercommunicative network—often with emergent characteristics that would not be predictable from the behavior of the individual subunits (synergetic emergentism). Moreover, a state is defined as the overall arrangement, orientation, physical and energetic characteristics of that system at any instant of time.

Definition of the Living State –

A physical system far from thermodynamic equilibrium that intelligently utilizes its low entropy configuration to control and engineer matter and energy in a goal-oriented manner, usually though not necessarily to maintain and replicate the low entropy state.

The demarcation between abiotic "non-living" matter and physical systems that are "alive" is the observable intelligent utilization of a low entropy configuration to manipulate matter and energy in a goal-oriented manner, usually— though not necessarily— to maintain and replicate the far from equilibrium thermodynamic state. There are many natural situations in which a far from thermodynamic equilibrium state arises. When a system develops within the far from thermodynamic equilibrium condition and the emergent system utilizes volitional behavior and intelligent operations to maintain or replicate the low entropy configuration via the control and engineering of matter and energy, that system is alive.

Here, we can perform a *gedankenexperiment* and imagine a scenario where a far from thermodynamic equilibrium state arises naturally, and there develops no emergent system that utilizes the low entropy configuration of the state for information processing to intelligently execute operations, which maintains and proliferates that low entropy state. In such a case scenario, the state will end once the conditions that give rise to the far from thermodynamic equilibrium cease. This serves a poignant distinction between mere low entropy configuration states and those manipulated and engineered by an intelligent system with the goal of maintaining, replicating, and /or proliferating the low entropy configuration and the information dynamics it enables in the physical system via intelligence.

The far-from-equilibrium thermodynamic state is not the key feature of the living state, but a necessary condition for entropy-infodynamics, like signal input (sensory information), homeostatic analysis, memory, and execution of operations (behavior). The key feature of an ensemble of matter and energy that demonstrably satisfies the definition of being alive is the intelligent utilization of low entropy configurations of matter and energy to control and engineer matter and energy in a goal-oriented manner—wherein goal-oriented behavior is manifest as a result of a system possessing non-predictable adaptive response pathways, also referred to as stand-alone volition, which is a defining quality of intelligent behavior and a condition of the non-computability of consciousness. It is the *intelligence* and observable goal-oriented behavior that demarcates a system as alive and is the distinguishing characteristic between abiotic matter (which in some cases may be quite structurally or dynamically complex and even verge on life-like activities) and living matter.

This provisional definition is a common feature to all living organisms, and will potentially be observed in the not-too-distant future in synthetic living systems, therefore the criterion is generalizable to any configuration of matter and energy and is requisite for a system to display the characteristic of being alive. It can be measured and observed, so that a system, whether organic, non-organic, or synthetic, can be positively and unambiguously identified as satisfying the definition of a living state, and hence is alive.

A key feature of living systems is learning. Learning requires the capacity for recording information, or memory. Memory, and hence learning results in adaptability, or evolution, and non-programmable behavior of a system. This results from the recursive nature of memory and learning, in which information fed into a system is recorded and processed, changing the state of the system, and the result is fed-back into the global system. This continues in a re-iterative process. Thus, recursive and iterative feedback operations are a key mechanism underlying life and a demonstration of the intrinsic intelligence and stand-alone volition of the natural living state.

If a system conforming to the definition of life is observed for an appropriate length of time, the key feature of goal-oriented behavior will become evident. Goal-oriented behavior, what here is referred to as stand-alone volition, results from non-programmable responses to stimuli of states. How does non-programmability arise? In materialistic mechanics, everything is the result of programmed responses. Because constants, laws, and in the case of neurocomputational consciousness: genes and circuitry, are the pre-programming from which all ordering and animating dynamics arise. Under this paradigm, all spacetime-matter events are computational and predictable.

However, it is possible to demonstrate that life exhibits non-predictable behavior— responses that cannot be programmed. The key defining characteristic of life and the living system is non-computational non-programmed behavior that arises from intrinsic intelligence and stand-alone volition. It can further be demonstrated that non-predictable, goal-oriented behavior arises from a degree of self-awareness, that forms a spectrum among living systems, as goal-oriented behavior is predicated by a certain level of awareness within a system that it is a “self”—an individualized distinct and delimited system that is distinguishable to a certain extent from the environment (even though the individualization is limited since it is always a subsystem of the environment, and certainly a subsystem of the universe). The degree of self-awareness is correlated with the degree of memory and learning capabilities of the system.

Goal-oriented behavior can therefore be used to positively, and objectively determine when a system has consciousness.

Life necessarily requires consciousness to create the awareness that allows for self-directed action. If there is no consciousness, there is no capacity for awareness, and therefore all observed behaviors of an object or system will be the result of extrinsic forces acting upon the object or system and will thus be passive responses with no volition attached to them whatsoever. This is a good definition for an automaton – a nonliving, mechanical system that responds to environmental stimuli with no stand-alone volition or self-directed behavior. Under the current consensus paradigm, all living beings, including humans, are considererd automatons [3].

Definition of a living system –

A delimited configuration of matter and energy that contains stand-alone volition, which can be identified by intelligent and goal-oriented behavior.

Critical points on the Definition of a living system:

Note that the definition of a living system does not include anything about the specific constitution of the system, such as a requirement that it be composed of organic molecules, or any requirement for demonstrating the capacity for growth, reproduction, functional activity, or continual change preceding death. While being highly similar to organic life in terms of energy requirements, a living system is a more general state of matter and energy, differentiable from organic lifeforms by the fact that it does not necessitate the inclusion of organic molecules within the ordered system. Put another way**, while all organisms are living systems, not all living systems are organisms.**

The defining characteristic of a delimited arrangement of matter and energy being identified as a living system is intelligence and goal-oriented behavior. This means that the living system is defined by the attribute of sentience within matter—matter that forms a sentient system.

Definition of a sentient system–

A system that orders matter and energy into states containing meaning to that system and uses the information contained therein to execute actions or perturbations of pre-existing states to affect outcomes based on the stand-alone volition of the system in a goal-oriented manner.

Critical points on the Definition of Sentience:

A sentient system necessarily conforms to the definition of a living system and vice versa. Information is energy or states of matter that have been ordered in such a way that the states have meaning to the system that has ordered it, and therefore a sentient system requires the arrangement and dynamics like that found in the living system—namely far-from equilibrium thermodyanimcs— in order to assign states of matter and energy informational quality, read and process the emergent syntax, and execute actions based on the meaning accessible to the arrangement of matter and energy based

on its sentient properties. Spacememory is a fundamental naturally sentient system as it is a universal neuromorphic network, it is also, therefore, a living system. Accordingly, the universe is a living sentient system.

Sentience necessarily requires consciousness, for that is what imbues the system with the awareness necessary to have stand-alone volition, reflexive introspection, and thus goal-oriented behavior. Awareness, the state by which qualitative properties of the universe are experienced, is an ontological primary and fundamental attribute of nature. Awareness imbues arrangements of matter and energy in the universe with sentience, whereby when thermodynamic conditions are favorable (far-from equilibrium) there is directional intelligence able to further order those networks of matter and energy into a sentient system. Via awareness, a sentient system has stand-alone volition, and thus can order and direct matter so as to maintain and / or expand the far-from equilibrium info-dynamic state forming a living system. The living system can be identified as alive via the goal-oriented behavior and intelligence arising from the sentience and stand-alone volition of the system.

Consciousness

Consciousness is the phenomenon of experience. From a purely physics point-of-view, there is no reason why any physical state, process, or property of the universe should have an associated experience of that state, process, or property by any particular configuration of matter in the universe. Indeed, it currently not possible to explain how a particular configuration of matter and energy in the universe is able to have an awareness and experience of qualia. This phenomenon referred to as consciousness requires an *experiencer*: that is a system with sentience, a system that forms a subject within which there is a quality to experience i.e., subjective experience of qualia. The predominant approach within conventional scientific thought is to posit that consciousness is an epiphenomenological state generated by the electrochemical activity of the brain. This approach makes consciousness a “hard problem” within the conventional purview of science because an epiphenomenological approach is unlikely to ever explain how a collection of matter and energy suddenly generates an awareness, or *experiencer* that is able to have a qualitative experience of objective states that have no inherent subjective qualities (within the cartesian duality of conventional scientific theory).

That is why it is posited here that awareness is an ontological primary. All states of matter and energy in the universe have a corresponding experience; there is a fundamental basal awareness and sentience that is an intrinsic and indelible component of the dynamics that produce the laws, constants, and forces of the universe. At the quantum scale, this is characterized by the entanglement network of spacememory, comprised of a multi-connected spacetime geometry of micro-wormholes, and at cosmological scales by the cosmic web—from the smallest to the largest scale there is a neuromorphic network that is naturally sentient and the reservoir of primary awareness within the universe. Living systems, like humans, are tapped into this universal neuromorphic network, and that is where awareness and sentience is sourced in these living systems. The living system emerged from the coupling of molecular matter with the neuromorphic network of spacememory, which gave intelligence and goal-oriented behavior to biochemical networks, and as these biochemical networks evolved into cells, metazoans, and animals the intrinsic intelligence and goal-oriented behavior of the molecular networks was expanded to include multi-level domains of the organism with scale-free cognition. High order

molecular levels of this holofractal nested architecture of scale-free cognitive domains developed refined and sophisticated specializations of the basal awareness of intrinsic consciousness, such as conceptual awareness and self-awareness.

From this, we can see that in theory it is possible for artificial (man-made) systems to be engineered and constructed in such a way that they are coupled to the spacememory network such that the basal awareness and natural sentience is operational within the artificial system's functionality. This will most likely have to be done at the nanoscale, with nanomolecular engineering to achieve a level of information coupling with the nonlocal neuromorphic network of the universe that the artificial system contains scale-free cognition and intrinsic awareness. This raises the question; how will we know whether such an artificial system is really conscious?

The current consensus criterion for assessing whether an artificial system is conscious is the Turing Test. The Turing Test posits that if in the interaction of a human with an artificially intelligent system, the human is unable to distinguish whether they are interacting with another human or an artificial system, that artificial system must be conscious. However, as will be explained, the Turing Test is not a viable criterion to assess whether or not an artificial system has awareness and is conscious. An artificial system can be sufficiently programmed to be indistinguishable from the behavior of a human. But programmed responses are the opposite of a system with agency. The true test of whether a system is conscious is if it can be ascertained that the system gives *non-programmed responses*. In addition to serving as a test for assessing whether an artificial, or natural system like an animal, possesses consciousness the following criterion also demonstrates a key characteristic of consciousness—that it is non-computable and non-programmable.

Criterion for Identifying if a System is Conscious –

A system that demonstrates goal-oriented behavior / stand-alone volition (volitional behavior that is non-programmable) is aware and possesses consciousness.

Methodology to Empirically Ascertain if a System is Conscious

Note: if a system is conscious, by the definitions herein, it is alive. And conversely, if a system is alive, then it has a certain level of consciousness, whether a basal-level of awareness possessed by a unicellular organism, or the complex cognitive-level of awareness of *Homo sapiens sapiens*— or somewhere within the spectrum between the two examples given. If a system is found to exhibit goal-oriented behavior, it can be assumed that it has stand-alone volition, which means that there is a certain level of self-awareness—i.e., the system behaves as if there is a certain level of awareness of "self".

To ascertain if a system is alive / conscious it must be tested against the null hypothesis that all behaviors, actions, and processes of the system are programmed responses in which any seeming goal-oriented behavior is a simulacrum of intelligence and in fact the system is an automaton. The null hypothesis is the default assumption of conventional scientific theory, whereby all manifestations of intelligence are superficial (there is no intrinsic intelligence) and all processes, even those of the living system, are the result of blind automata, and as such can be fully replicated by a computational program:

> *Note, this is why the idea that the universe could be a simulation is popular, as it is assumed that every aspect of the universe can be replicated by a blind, non-living program. The simulation hypothesis is another instance of the inclination of scientists to equate whatever the present era's apex technology is to the underlying function of everything in the universe. Thus, the brain is a computer, genetic algorithms are computational, as is the fundamental interactions of matter. The problem, however, is that today's digital computers are not the ultimate apex information processing technology. If there will be an apex information processing technology, it will be based on the way the universe naturally organizes and exchanges information, which is not computationally based. digital computers (our most advanced present means of information processing) will seem technologically rudimentary to future quasi-instantaneous information processing systems, like the exchange-free quantum computer (utilizing traversable wormhole teleportation). Hence, for example, the mind and the physiological correlates of mental processing are not performing sequential digital computations to remember past states (memory) where a network of neurons represent "on" / "off" binary values— but instead, there is an instantaneous direct accession of past states (and even potential "future" states) via the temporal entanglement of the intrinsic multiply-connected wormhole network of space. A computer based on the same principles will not so much process information, but instantaneously access the output (this can also be thought of in terms of the multiverse: in which there is access to parallel universes where "answers" have already been computed and are therefore available in universes where the actual sequential information processing has not yet physically occurred). Since quasi-instantaneous information accession via the spacememory network is how information is naturally ordered and communicated within the universe, it will not be possible to fully simulate the universe via rudimentary binary digital computations.*

To test if a system is conscious, a behavior must be identified as exhibiting the quality of volition, i.e., the system performed a certain action to achieve a particular outcome or terminal state, a goal. It must be assumed that the behavior is a programmed response, and only a simulacrum of teleological function or volitional purpose. This assumption must be tested by setting up the conditions required to repeat the behavior, but introducing conditions that will inhibit or block the execution of that behavior, and hence impede the system from achieving its "goal". If it is a programmed behavior, the program will be blocked by the change. If, however, it is the behavior of a truly sentient system, the system will exhibit adaptive behavior, and change its actions in response to the perturbation to achieve the terminal outcome or goal. This kind of adaptive response is the hallmark of intelligence—the ability to achieve an outcome (a goal) even against changing

conditions and unforeseeable impediments.

It is possible that the system has adaptive programming, so perturbations must be sequentially introduced until it is sufficiently demonstrated that the system's behavior is unpredictable, and hence not programmed. The system can no longer justifiably be considered an automaton, the adaptive behavior can no longer be considered a simulacrum of intelligence, and it must be reasonably considered that the system contains a certain level of self-awareness, is conscious, and hence is alive.

Since consciousness is an ontological primary, and a subjective experience of qualia by an*experiencer*, it is impossible to empirically prove with 100% certainty that a system is conscious. However, the criterion defined herein and the methodology to assess the criterion can be utilized to approach a definitive answer to whether a system is alive and / or conscious with a reasonably high degree of confidence, which should be sufficient in most circumstances to treat the system as sentient (i.e., to avoid causing undo suffering to the system or arbitrarily terminating its sentient / living state).

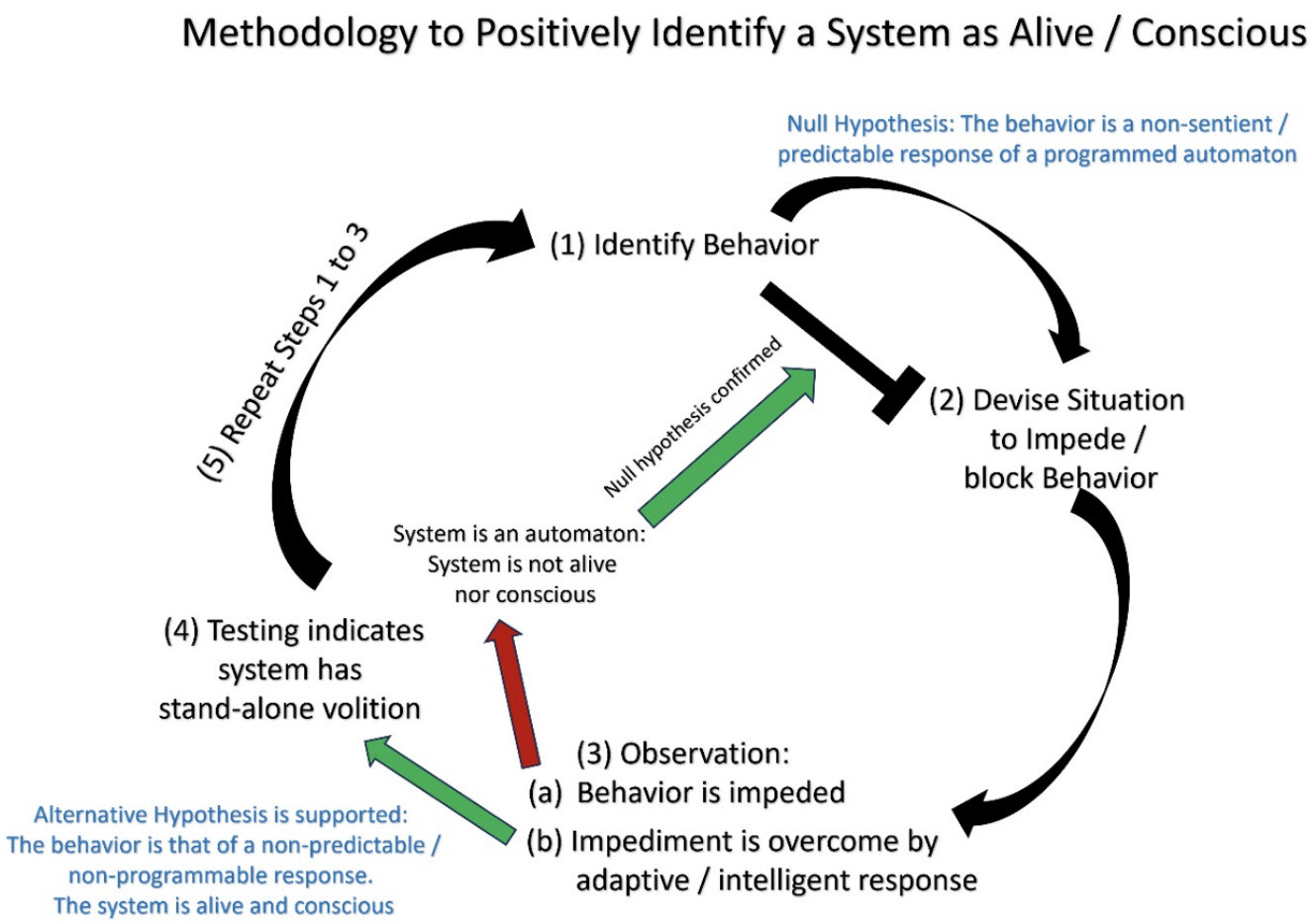

Figure 1. Diagram for empirical methodology to positively identify a system as alive and conscious.

Conclusion

Life is defined to be a particular state exhibited by a system's tendency to behave as if it were a distinct entity, with goal-

oriented, or volitional behavior. By this definition, something that would normally be regarded as living would be defined otherwise. For example, a single cell could be reduced to a veritable biochemical factory, in which there is no observable behavior of stand-alone volition, such as reproduction or action taken to thrive. The cell would not technically be defined as alive, although it is obviously a biological system, it can be manipulated is such a way as to become an automaton. Conversely, if a machine, which we would normally regard as non-living, were to demonstrate awareness of itself as a distinct entity, and exhibit stand-alone volition, it would be regarded as conscious – and hence *alive.* Therefore, there is a universality to consciousness and life – it is not simply restricted to a biological, organic system.

These are technical definitions, aimed at approaching a more refined, and precise approximation of what consciousness and life is, and enabling an unambiguous means to identify these qualities. These definitions are taken to be provisional, as future theoretical and empirical developments may provide an update and refinement of the definitions (since this is about understanding and not "being right", such revisions will be welcomed). Fundamentally, information flows continuously through all systems at all scales, via spacememory of which everything is comprised, and as such, life and consciousness may be connected in all things. However, there is an objective and qualitative difference in systems that depends on the degree to which consciousness and life are *exhibited*. Even high-energy plasmas under certain experimental conditions can exhibit very life-like qualities, and yet, there is little moral objection to "pulling the plug" on these systems once an experiment is concluded. By the definitions outlined in this paper, guidelines can be established from unambiguous criteria to provide for ethical practices in the treatment of systems that are identified as being alive.

References

1. ^*N. Haramein, W. D. Brown, and A. Val Baker, "The Unified Spacememory Network: from Cosmogenesis to Consciousness," Neuroquantology, vol. 14, no. 4, Jun. 2016, doi: 10.14704/nq.2016.14.4.961*
2. ^*Martin M. Hanczyc; Engineering Life: A Review of Synthetic Biology. Artif Life 2020; 26 (2): 260-273. doi: https://doi.org/10.1162/artl_a_00318*
3. ^*Dawkins, Richard. The Selfish Gene. Oxford University Press, 2006.*