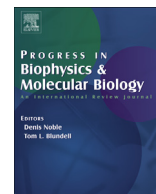




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Biological evolution as defense of 'self'

William B. Miller Jr.^{a,*}, John S. Torday^b, František Baluška^c^a Paradise Valley, AZ, United States^b Department of Pediatrics, Harbor-UCLA Medical Center, 3887, USA^c IZMB, University of Bonn, Kirschelallee 1, 53115, Bonn, Germany

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ABSTRACT

Although the origin of self-referential consciousness is unknown, it can be argued that the instantiation of self-reference was the commencement of the living state as phenomenal experientiality. As self-referential cognition is demonstrated by all living organisms, life can be equated with the sustenance of cellular homeostasis in the continuous defense of 'self'. It is proposed that the epicenter of 'self' is perpetually embodied within the basic cellular form in which it was instantiated. Cognition-Based Evolution argues that all of biological and evolutionary development represents the perpetual autopoietic defense of self-referential basal cellular states of homeostatic preference. The means by which these states are attained and maintained is through self-referential measurement of information and its communication. The multicellular forms, either as biofilms or holobionts, represent the cellular attempt to achieve maximum states of informational distinction and energy efficiency through individual and collective means. In this frame, consciousness, self-consciousness and intelligence can be identified as forms of collective cellular phenotype directed towards the defense of fundamental cellular self-reference.

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Now there are selves. There was a time, thousands (or millions, or billions of years ago), when there were none- at least none on this planet. So there has to be - as a matter of logic- a true story to be told about how there came to be creatures with selves. Dan Dennett, 1989

1. Introduction

In a series of prior articles, the major tenets of Cognition Based Evolution as an alternative to standard Darwinism have been enumerated (Miller, 2013, 2016a, 2016b, 2017, Miller and Torday, 2017, 2018). In particular, it has been previously defended that life requires cognition at every scale (Shapiro, 2007, 2011; Baluška, and Mancuso, 2009; Trewavas and Baluška, 2011; Bechtel, 2014; Dodig-Crnkovic, 2014, 2017; Torday, 2015; Lyon, 2015; Baluška and Levin, 2016; Miller, 2016a, 2017; Ford, 2009, 2017; Koseska and Bastiaens,

2017; Keijzer, 2017; Vallverdú et al., 2018). It is now proposed that the difficult issue of 'self' that underpins biology as phenomenal experientiality might be productively examined from within the standpoint of cellular cognition and the further hologenomic entanglements that enable complex macroorganisms.

As self-conscious beings ourselves, one of the major difficulties in any dissection of the topic of consciousness is that there is necessary subjectivity and a general entailing bias. That crux resides within two roots. First, our living experience convinces us of our oneness as an organic singularity. Yet, accumulating evidence indicates that we are a multi-species collective functioning as a holobionic partnership between our innate cells and an obligatory microbial fraction (Miller, 2013, 2016a; 2016b; Gilbert, 2014; Miller and Torday, 2017; Torday and Miller, 2017a; Rees et al., 2018). Therefore, simply apprehending that our singular 'self' is an illusion requires a significant act of self-abnegation. Our second categorical bias is our conviction that our species is the most intelligent in all relevant respects. It is obvious that there are some truths to that presumption. However, a counter-argument can also be supported. Our attitude that all other life forms are subordinate is largely reflexive self-approbation. Our valuation of our own idiosyncratic faculties is based upon our stubborn reluctance to view alternative forms of intelligent problem-solving in unhuman terms (Trewavas, 2005; Lyon, 2006; Witzany, 2006; Qin and Wheeler, 2007; Baluška

Abbreviations: PIF, Pervasive Information Field; EI*, effective information; MAM, mitochondria-ER associated membranes.

* Corresponding author.

E-mail addresses: wbmiller1@cox.net (W.B. Miller), jtorday@ucla.edu (J.S. Torday), unb15e@uni-bonn.de (F. Baluška).

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and Mancuso, 2009; Ford, 2009, 2011; Trewavas and Baluška, 2011; Westerhoff et al., 2014; van Loon, 2016).

That presupposition of hierarchical intelligence is usually framed from within two premises: our type of acumen is the correct measure of a planetary scale of intelligence, and further, the seeming primacy of our gifts, as enacted within this geologic moment, is the pertinent dimension of that supremacy. Therefore, it is not surprising that both human language and our abundant technical achievements are considered the proving exemplars of that preeminence. Yet, might we be mistaken? Could our cognitive position within an entire planetary narrative be differing from our natural instincts?

Stephen Hawking has a widely known definition of intelligence that might permit a debate. In his terms, "Intelligence is the ability to adapt to change". If that is deemed the proper benchmark, then, our form of intelligence, which has only asserted its predominance for fewer than two hundred thousand years, is still little tested. In contrast, it can be argued that the epicenter of certifiable intelligence is invested within the basal self-referential unicellular domains that have demonstrated continuous successful adaptation over billions of years (Miller and Torday, 2018). When that continuous self-referential integrity is honored, it can be further advanced that evolutionary development is a narrative of the continuous defense of self-referential cognition as it is perpetually embodied within these base cellular forms (Miller and Torday, 2018). By inference then, macroorganic biological and evolutionary development should be considered on the basis of individual and collective self-referential cellular behaviors, their requisites, and the nature of the informational matrix upon which they depend.

2. Conscious self-reference

2.1. Previous considerations

The issue of self-referential consciousness remains an enigma. There is a general definitional fluidity that characterizes any discussion of consciousness and qualia (Grandpierre et al., 2013). Any productive interrogation is hindered by obvious barriers in the precise quantization of subjective experience (Cleeremans, 2005; De Graaf et al., 2012; Feinberg and Mallatt, 2016.). Despite any objective uncertainties, it can be assumed that scientific fundamentals should apply and that these principles should extend and amplify over the course of evolution (Panksepp, 2004; Noble, 2010; Mashour and Alkire, 2013). Therefore, even if consciousness is to some degree irreducible, it is most likely supervenient (Chalmers, 1996).

For some, the awareness of experience has been taken as a fundamental property that cannot be reduced (Chalmers, 1996; Theise and Kafatos, 2016). Trewavas, A.J. and Baluška (2011) regard self-awareness as a ubiquitous feature of the living state. They quote Margulis and Sagan from 1995, "Not just animals are conscious but every organized being is conscious. In the simplest sense, consciousness is an awareness (has knowledge) of the outside world" (Trewavas and Baluška, 2011). This depiction echoes Maturana (1970), who proposed that the living state must be regarded as the process of cognition. Shapiro (2011), too, directly contended that life requires cognition at every scope and scale. Of course, such ideas are not only modern. Ancient Eastern philosophies have offered a similar perspective. Shanta (2015) asserts: "Life is essentially cognitive and conscious. And, consciousness, which is fundamental, manifests itself in the gradational forms of all sentient and insentient nature. In contrast to the idea of objective evolution of bodies, as envisioned by Darwin and followers, Vedānta advocates the idea of subjective evolution of

consciousness as the developing principle of the world."

From that conflicting base, pertinent questions arise. How do 'self-reference', 'consciousness' and 'self-consciousness' interrelate? How do sentience, cognition, intelligence and qualia entwine among these? A particular continuing issue is whether consciousness can be effectively discriminated from self-consciousness. Perlis (1997) thought not, proposing that self-consciousness is not an epiphenomenon but a fundamental essence of consciousness as its most basic architectural form. Thus, consciousness should be viewed as a 'special' type of self-referential awareness (self-consciousness). Gennaro (1996) defended that, "consciousness entails self-consciousness" (p. 1). Yet, Jackendoff (1987) proposed differently, holding that self-consciousness is a mixture of consciousness and self-reference where each can be deemed separable. Zeman (2005) examined the contrasts of wakefulness and sleep and proposed that consciousness is distinct from self-consciousness. In those terms, self-consciousness might be considered as self-detection and self-recognition as an 'inner' consciousness that stands apart from a larger conscious state. When such a distinction is made, it suggests that consciousness might be subdivided. This division has been considered the 'hard' problem of subjective experientiality that can be differentiated from an 'easy' problem that consists of those identifiable structural or molecular sequences that underlie neurobiology (Chalmers, 1996; Zeman, 2005). Others have attempted to split the difference, judging consciousness as a rough equality with autopoiesis (Bojadžiev, 2000).

One consensus tends to stand apart. There should be a reductive explanation for consciousness that is discretely available to science through a materialistic approach. Yet, even here, not all agree. Pereira and Reddy (2016) express doubt that a reductive approach can ever be successful. Instead, they insist that research must be directed towards non-local phenomena and the non-material aspects of living organisms. Still, even if self-referential consciousness as phenomenal experientiality is non-reductive, it might still be reasonably supposed that there is a physical basis through which it acts even if by non-conventional means (De Loof, 2016; Torday and Miller, 2017b; Baluška and Miller, 2018).

An additional problem must also be considered within the mix of opinion. While the individual capacity for self-reference is perplexing, it is equally surprising that it is so alike as to permit extremely effective communications among living entities. Across the living spectrum, informational experiences are shared in direct consequence of environmental inputs and stresses. As a general rule, similar organisms widely share subjective experiences. Acknowledging this, Chalmers (1995) has offered that consciousness has both structural coherence (awareness of information has isomorphic linkage to consciousness) and substantial organizational invariance (systems with the same organization will have the same experiences). This led him to argue that information space-time has dual properties, "... a physical aspect and a phenomenal aspect. This has the status of a basic principle that might underlie and explain the emergence of experience from the physical. Experience arises by virtue of its status of one aspect of information, when the other aspect is found embodied in physical processing." (p.19). From this, Chalmers (1995) postulates that information is itself fundamental to phenomenal experientiality.

To date, the exact means by which consciousness arose so that it might have a physical correlate that could reduce to conscious self-awareness has proved elusive (Feinberg and Mallatt, 2013). Hammeroff and Penrose (2014) proposed three general possibilities for the enigmatic origination of consciousness as it might translate to physical action. First, consciousness may lie apart from any universal feature, arising as a natural emergent function of biological computation based on evolution due to conventional

physical laws. In such a case, it would be unclear as to when it developed on the evolutionary scale. Alternatively, it could be an intrinsic feature of the universe as a panpsychic consciousness attributable to all matter and is thus beyond scientific explanation. Within this frame, only consciousness exists and the material realm is illusory. And lastly, consciousness might have derived via discrete physical events from a pre-existing proto-consciousness that achieves coherence through quantum state reductions that yields cognitive behavior, essentially as intrinsic self-measurement. This latter perspective, sharing some general overlap with the views of A.N.Whitehead, becomes the basis of their attempt to address consciousness through quantum means by their OrchOR theory (Hameroff and Penrose, 2014). They proposed that the nature of consciousness is brain centered and dependent on quantum coordination of cellular microtubules that can be 'biologically orchestrated' to regulate neuronal synaptic and membrane activity. That orchestration provides a linking pathway that connects our conscious awareness with a basic structural consciousness of the universe.

The integration of such quantum phenomena (quantum brain/mind) in the realm of consciousness has gained considerable currency, particularly with findings that document quantum phenomena in aspects of photosynthesis, directional magnetic effects in migrating birds and animals, and in the olfactory apparatus (Tarlaci and Pregnotato, 2016; Pytkkanen, 2014; Hameroff et al., 2014; Torday, 2018). Yet, there is no clarity as to the exact means by which quantum phenomena might be applied to the issue of self-reference. Hankey (2014) examined this discrepancy, noting that a background assumption has been made that insofar as mind cannot be specified through classical physics, it must be due to quantum physics by default. It could be supposed that a reduction within the realm of quanta must yield mind-matter interactions. Yet, Hankey (2014) offers a differing path. Consciousness is the result of 'critical instabilities' that create 'self-organizing criticalities' in which the flows of information loop back upon themselves to create 'perfect self-observation'. In such a system, quanta are destroyed, so that instability fluctuations that cannot be quantized predominate. In effect, it is not resonances that create self-reference, as might generally be supposed, but anharmonic fluctuations that exist within coherent negentropy. Such variances cannot be digitized or computed, but, nonetheless, have high internal coherence through a stream of uniting information vectors (Hankey, 2014). There is some support for this perspective. Longo and Montévil (2013) argue that biology is characterized by ubiquitous critical phase space point transitions. Bak (1996) has even proposed that all natural events, including biological ones such as extinctions, are due to such non-linear self-organizing criticalities and instabilities.

Despite this expansive variety of opinion, it is nonetheless argued that an orderly structural characterization of self-reference, self-consciousness or consciousness can be offered. That opportunity arises through an examination of how basal self-reference defines its own scope within the cellular form. It is proposed that from this epitomic centrality, a further understanding of consciousness, self-consciousness, and the disparate intelligences exhibited across the living spectrum can be gained.

2.2. Self-reference and ambiguity

It has been previously proposed that basal self-reference was instantiated as an orthogonal of thermodynamics through its attachment to biological information space-time in which biological cues are inherently ambiguous (Miller, 2016a, 2017). This transition was achieved through, or at least embodied within, the cellular form. In particular, it is asserted that the instantiation of

self-reference was the simultaneous alpha of biological observer status and the birth of the implicate realm. Thus, the instantiation of self-reference commenced the living state by permitting choice and contingency among subjective observer/participants through an attachment to biological information (Miller, 2016a, 2017; Torday and Miller, 2017b; Miller and Torday, 2018).

For any self-referential observer, physical data becomes biological information. The difference is that biological information, unlike physical data, is a set of overlapping implicates that is characterized by any self-referential observer as inherently ambiguous. In the living circumstance, implicates become choice contingencies at all scales. These are not probability sets based on quantum stochastic calculations but self-referential equivocality which do not settle into biological expression based on statistical probability. Instead, such implicates represent overlapping instabilities whose fluctuations settle in a manner that has substantial barriers to direct quantitative analysis (Hankey, 2014). Significantly, self-referential observation is dependent upon shifting and imprecise inputs that are themselves deviated by self-referential measurement. Thus, every aspect of the living state has inherent uncertainties.

As Ho (1998) had insisted, life must be understood as the process of being an 'organizing whole'. Research in cellular and microbial cognition indicates that the source of this organization is the self-referential capacity within any living organism that permits the quantification (measurement) of imprecise informational inputs. Therefore, life can be appropriately considered a form of information processing (Farnsworth et al., 2013; Miller, 2017). From this, a straightforward 'intent' of life can be proposed. It is the consistent drive towards Effective Information (EI*). Farnsworth et al. (2013) suggest that this concept of EI* is best quantified as information that permits an organized system to perform non-random actions. This definition derives from the description of functional information by Szostak in 2003. Therefore, EI* is information that permits the cell to efficiently uphold its self-referential equipoise versus the external environment beyond random adjustments despite ambiguous background noise.

In biological information space-time, any living expression is the result of the settling of the critical instabilities that are inherent to ambivalent information space. These ultimately resolve through internalized coherences into eigenstates with quantifiable characteristics which might still rapidly decohere back to chaos (uncertainty) (Mohensi et al., 2014). For any self-referential organism, those coherences represent a confluence of information vectors which represents those sources of information that it subjectively chooses to emphasize. Yet, there is a necessary precondition. As any organism attaches greater certainty to any one variable input towards any particular eigenstate, there is a concomitant increase in the uncertainty of other variable and relevant inputs. This is a requisite reciprocal of the self-referential state. As a self-referential organism seeks greater certainty of information directed towards one aspect of its self-referential status, other inputs must be lesser, since the capacity for information assessment is not unlimited. Thus, a living organism that 'knows' its stressful circumstances by one measure of experience and concentrates its responses towards it, confronts an obligatory range of opposing informational equivocality about other aspects of its external environment through its own internalized constraints. Non-living objects, even if imbued with any theoretical cosmic consciousness, do not respond in like manner. Simply put, 'knowing' equivocality at the most basal level is a consistent state of flux within a perpetually non-equilibrium entity. It is argued that the epicenter of this 'knowing' in basal biological terms is the explicit realm of the bounded cell.

Cells aggregate through mutual associations and competition, share resources, and problem-solve through both individual and

collective means, either as biofilms or holobionts. Such associations are enabled through the basal self-referential awareness that is embodied within cells as part of their entire panoply of faculties. These constitute its limited form of cognitive intelligence (Ford, 2004, 2009; 2017; Baluška and Levin, 2016; Miller, 2016a, 2017; Miller and Torday, 2018). Clearly, cells sense sufficiently to maintain homeostatic equipoise and can further apply some limited measures of prediction and anticipation (Ford, 2004, 2009; 2017; Hellingwerf, 2005; Ben-Jacob and Levine, 2006; Ben-Jacob, 2009; Mitchell et al., 2009; Xavier et al., 2011). An ample range of objective cellular faculties attest that all living organisms demonstrate self-referential cognition. These include individual perception/sensing, collective sensing and cooperation, complex communication, indirect sensing through proxies, memory, avoidance learning and behavioral adaptation, computation, combinatorial problem-solving, the active trading of resources, and sociality (Lyon, 2015; Ramanathan and Broach, 2007; Bray, 2009; Freddolino and Tavazoie, 2012; Dong et al., 2001; Williams et al., 2007; Jacob et al., 2006; Shapiro, 2007; Bruger and Waters, 2015; Pinto and Mascher, 2016; Mathis and Ackermann, 2017; Goo et al., 2012; Tagkopoulos et al., 2008; Tasoff et al., 2015; Rubens et al., 2016; Reber, 2018).

It is plain that these manifestations of cognitive capacity are themselves dependent on phenomenal experientiality as their source. Thus, phenomenal experientiality is invested within cells as basal self-consciousness sentience (self-referential awareness of status) as its own limited qualia. It is further proposed that this might be considered a quantifiable progenitor form of any further aspects of self-referential awareness that is variably augmented along an evolutionary scale. Thus, cellular cognition should be considered the first stanchion in an edifice that consists of the spectrum of consciousness, self-consciousness, and intelligences that are unevenly displayed across the planet.

2.3. The nature of self-referential information

Since self-referential awareness is dependent on both energy and information, there is a further requirement to consider the biological context of that complementarity. It is acknowledged that the universe is both energy and matter. It is further accepted that energy has both positive and negative states (Everett and Roman, 2012). So do electrons. Paul Dirac formalized a mathematical expression for negatively charged electrons traveling close to the speed of light and intuited that these equations implied positrons as 'anti-electrons' with a positive charge (Halpern, 2017). Matter also has dual forms (Greaves and Surko, 1997). Matter and anti-matter are particle and anti-particle with opposite charges and different quantum numbers (Tsan, 2012). Thus, as information is energy entrained, some weight must be given to framing information as having its own form of binary characteristics, which can be considered information and antipodal-information.

In a living informational matrix, there is more information than can be directly observed or sensed. Antipodal information represents information that might be obscured by physical limitations to one specific observer/participant but might be measurable by others, dependent upon context. It also pertains to categories of depth of information that are not readily accessible beyond general inference.

That there is available information in any information system that is not sensed is not the least surprising. The concept of antipodal information has been applied to information theory where it is considered akin to noise. Commercial communication feedback channels employ antipodal signaling, measurable in terms of amplitude and phase, to improve communication system performance (Srinivasan, 1981). It is proposed that knowledge of

space-time for self-referential agencies requires information to have an antipode by which it might gain symmetry (Matsui, 2001).

To approach this conceptually, it is suggested that information, rather than a data point, might be deemed 'round' with a volumetric spatial dimensionality. Antipodal information would be that aspect of total information content that is on the opposite side of the *en face* portion of the 'informational volume' that any organism consciously senses. It is proposed that any understanding of 'self' and its organizational ability must include the measuring value of additional information that can be accessed and processed which does not reach our conscious senses but is nonetheless relevant. This might roughly be analogous to subliminal influences that represent an inherent feature of information assessment. The summation of this information is always operative, yet only some of it is overtly sensed. The significant difference is that antipodal information is proposed as an essential aspect of the information space-time to which all organisms attach at every scope and scale. Importantly, this source of ambiguity is a structural component of information space-time in the living circumstance. It is not the result of the more obvious sources of organismal uncertainty such as signal degradation by transmission through an interfering medium or time delays in the delivery or reception of pertinent information. Yet, it is every bit as significant an influence on ambiguity in information assessment as direct interference in physical signal transmission.

It is suggested that antipodal information consists of four categories. The first type can be understood by considering information as a volume in which there is a 'side' that represents classical information and another that is just as real in information space-time but unappreciated by the same observer-participant. Thus, there is information that is readily assessed, and additional information that is still there but 'antipodal'. This is information that is context dependent to any particular observer or directly available to some observers but not others. This can be likened to the difference between a very young child's apprehension of a full moon as a disk in the sky, whereas an adult knows that only the front surface of a sphere is being observed. The amount of information that is available to direct inspection depends on the subjective status of the observer and can have very different meanings.

The second category is information on the adjacents as modeled by Marijuán et al. (2015). This regards supplementary information as 'distinction on the adjacent' and has been likened to the dimples on a golf ball that places some surface points of an informational matrix in closer apposition than others and thereby narrows the pathway between them (Marijuán et al., 2015). The 'distinction' represents the gap between information reception, its active internalization and its biological deployment. This has measuring value since 'adjacents' that can be brought in closer apposition by physical or non-physical means have more contextual meaning. In the frame of ambiguity, adjacents might permit less uncertainty.

The third form is the value of the spaces between any points of information in an informational space-time matrix. In the context of information, this is not empty space. Forshaw (2016) has termed these 'spaces' the 'Third State' representing a universal value common to all data and information that brings order and meaning within an informational matrix. This is most simply understood as the spaces between the words in this manuscript. Without them, all words would run together and interpretation becomes highly problematic beyond the word content itself. This further aspect of information is time-related. That such an issue of spacing is inherently sensed by an organism is not merely theoretical, since sensitization and habituation have both been experimentally linked to both frequency and amplitude of repetitive stimuli (Rankin et al., 2009). The fourth type is exclusive to the 'knowing' self-referential state. It is this information that is anticipated and

not received by a self-referential organism, the absence of which is itself a significant form of information.

Tozzi and Peters (2017) offers a corroborating conceptual framework that strengthens the concept of antipodal information, and suggest that it might be regarded as a unifying principle that underlies the organization of physical and biological systems. Based on versions of the Borsuk-Ulam Theorem, it can be upheld that a feature on a n -manifold, i.e. a roughly planar spatial surface, projects to two points with "matching description" onto an $+1$ manifold as a dimensional spheroid. Those two points on that sphere that represents the $+1$ manifold dimensions are 'matching' but are on opposite sides. In biological circumstances, instead of a simple matching description between those two points, A and 'opposite' A, becomes a ' Δ A' as its corresponding matching description. Although the two points have a matching symmetry, at the level of the $+1$ manifold, there is a subtle shift between them. They remain paired, but are no longer identical. As a result, there is a slight deviation of information compared to its opposite 'matching' partner at the level of the next dimensional manifold. This can be a consequential source of variation, which could have direct biological applicability. As Tozzi and Peters (2017) state, "In every subsequent mapping in higher dimensions, the diversity among the matching features increases, allowing a high rate of evolutionary variety." (p. 6) Therefore, any mapping from lower to higher informational dimensions continues to have related features that belong together but are not exact equalities. The higher the number of dimensions, the greater the drift which yields an opportunity for biological diversity.

As in all aspects of the living state, the gain in diversity from antipodal information drift has its opposing negative. Although this informational drift might provide feedstock for divergent forms of life, organisms must still cope with the accuracy of information to survive. Collective assessment of information through multicellularity is the problem-solving compensation for this inherent information drift of 'matching' antipodals at higher dimensions. The quality and precision of shared information improve through its collective subjective assessment, by multiple linked observer/participants, thereby compensating for antipodal drift. Therefore, *the dominance of multicellular mutualistic competition and collaboration is justified as a requisite entanglement for the assessment of dimensional information space-time*. A better understanding of information space-time requires delving into the unobserved interstices that any set of informational cues simultaneously maintains which includes antipodal drift, sets of adjacents, meaningful 'empty spaces' between points of information, and anticipated information that does not arrive. It is offered that all of these are aspects of total conscious self-reference and sentience for any organism. And it is argued that even the basic cell is attached to all of them as part of its prescribed self-reference.

Even noise is an important aspect of the self-aware assessment of information space-time. The consistency of background noise, or its sudden alteration or absence, is used by the cell as a 'harnessing of stochasticity' which permits the effective sorting of high amplitude data inputs from continuous lesser inputs (Noble and Noble, 2017). There is no doubt that noise matters. Habituation and sensitization are dependent upon it to assess sensory stimuli and both clearly have adaptive value that applies to protozoa and plants as well as animals (Eisenstein and Eisenstein, 2006; Gagliano et al., 2014).

This fuller conception of the complexity information space has some aspects in common with the concept of 'logic in reality' expressed by Brenner (2012) and that of 'absentials' formulated by Deacon (2011). Both find that the connection between information content and physical reality has an indefinite relationship since information lacks precise representational meaning. It consists of

both actualities and potentials. It is proposed that those in-between states that have been considered 'absentials' can be directly related to antipodal information. The advantage is that the various categories of antipodal-information are more amenable to measurement.

Ulanowicz (2011) has asserted that it is mistaken to regard information only in its apodictic (clearly established or beyond dispute) form. Instead, there should be an attempt to quantify 'that which is absent' as a crucial negative aspect of information that still has measuring value. He explored this complex topic in terms of Shannon information and Boltzmann's analysis of the statistical probability of non-interacting particles in a system. Boltzmann derived an entropic measure

$$H_i = -\sum p_i \log(p_i)$$

as a calculation of 'absence' or non-occurrence with ' p_i ' the probability that i has occurred within a total number of observations (Ulanowicz, 2011). As Ulanowicz (2011) explains, Shannon had realized that $-\log(p_i)$ was a good estimate of the degree of surprise for any observer. Large values of p_i , i.e., those closest to 1, are 'expected' whereas low values of p_i , relate to significant surprise. Friston et al. (2006) had asserted that organisms seek to minimize variational free energy in suppression of that surprise. It is argued that an attachment to antipodal information is a direct requirement of any information system directed towards that suppression of surprise. And also, as a further derivative, that 'absent' or antipodal realm contributes a systematic potential for flexibility (Ulanowicz, 2011). It can be considered that biological creativity is, in part, an attempt to make sense of this conflict within information space-time.

There are specific examples of the assessment of information that can be considered as operating within an antipodal set. For instance, colorblindness affects complementary colors, on the opposite sides of the color chart. Problems with red-green or yellow-blue colorblindness are both a function of genetic defects in cones and the brain processing of color perception (Sharpe et al., 1999). The relevant information is sensed by some and not others, but the color of the object itself can be strictly measured. Two other particularly pertinent examples can be offered that have been viral sensations on the internet. Both are instances in which the subjective assessment of identical information is interpreted as unequal by different simultaneous observers. One example is the subjective human distinction of a measurable audio spectrum, termed 'yanni' vs. 'laurel' (Hernandez, 2018). The other is the well-publicized difference in the subjective human assessment of the colors of the same striped dress (white and gold vs. blue and black) on the internet. In both circumstances, the best explanation is the ambiguity of information on the adjacents, and both are examples of antipodal information assessment intrinsic to every organism's existence and part of its continuous phenomenal experientiality.

It is further proposed that even inferred information can also represent aspects of awareness of antipodal information. For example, in looking at a curtain, a specific individual would see the front, but infer, from experience that there is a back that has a direct relationship to the front. Someone unfamiliar with curtains would not necessarily perceive that curtain in the same manner. Our perception of a curtain relies on a subjective apprehension of both the direct visual cue, and the inferential information, which is its hidden antipode to some subjective observers. Thus, by many overlapping means, conscious awareness becomes a function of a range of self-referential nuances.

Anticipation and prediction are also functions of a differing type of antipode. Often, their assessment is not a function of small deliberate differences between choices. The living circumstance is

frequently a matter of opposites, ...to leap, or to remain still, to hide, flee or charge. All of these can be considered antipodal expressions of a summation of informational cues. The implication derives then, that even an instantaneous assessment of information contains all of the elements that have been discussed, including direct apprehension and non-overt antipodals. All sensed data, including that which is unapparent, contributes to the equivocality and imprecisions of information in biological contexts from which biological decisions must be made.

It is now well accepted that quantum phenomena such as non-locality and entanglement are an important aspect of the living circumstance (Ho, 1998; Miller, 2016a, 2017; Torday and Miller, 2016a, 2016d; Torday, 2018). Yet, as Kafatos and Kak (2015) point out, we do not observe non-locality or superimposition in everyday experience. Nonetheless, they are presumed to operate. Therefore, our objective reality can be seen to operate at a level of connection to 'classical' local realism at the expense of non-locality, a phenomenon that has been termed 'veiled non-locality' (Kak et al., 2014). If so, the reception and assessment of information can be considered to be under a form of constraint that governs what information is perceptible and apprehended within a 'classical' referential state. By implication, there is much more information that an organism 'senses' as knowingly perceived by any self-referential organism. Experience is therefore both classically subjective and quantum-related, and both are processed simultaneously. On a conceptual basis, this is a dual informational architecture. The 'interstices' of informational space-time remain 'veiled' to our senses as a menu of superimposed implicates as our 'subconscious', that nonetheless still have purchase on explicate biological expression.

From this background, the concept of an informational architecture proves useful (Marijuán et al., 2015; Walker et al., 2016; Miller, 2016a, 2017; Miller and Torday, 2018). It has been previously argued that information cannot be regarded as merely a collection of points, each as a constellation of superimposed implicates, but should instead be projected as an information field to which living organisms attach (Miller, 2016a). Such Pervasive Information Fields (PIF), modeled after work first done by Lloyd (2002), have been conceptualized as the summation of all available sources of information for any specific self-referential observer/participant. The distinct advantage of envisioning information as a field is that energy is also viewed in that manner, which reinforces that energy and information are interconvertibles (Miller, 2017).

The further advantage of the information field concept is that it melds well with proposed models of states of gauge symmetry. For particles in those states, a change in direction between space-time points has a direct relationship to gauge potentials within gauge symmetries (Longo and Montévil, 2014). Although further exploration of this complex topic is beyond the scope of this article, it has been asserted that brain activity may be driven by gauge fields through the maintenance or breakdown of these types of gauge symmetries (Tozzi et al., 2017). Pertinently, Krakatos (2014) analogizes the concept of 'symmetry breaking' from particle physics to the experiential living state through three fundamental principles: complementarity, recursion, and sentience (Kafatos, 2014). Complementarity is the unifying principle of quantum mechanics where 'apparent' opposites become unified. Thus, complementarity is important to any theory of information in which antipodes are presumed. Recursion assumes "as here, so elsewhere" and assures that self-referential organisms react to information with sufficient self-similarity to enable collaborative assessment of information space-time. And, environmental sentience is the critical correspondent between internal and external states that maintains homeostasis as the basis of information assessment, cell-cell

communication, and the deployment of information. It is proposed that an organism's attachment to its own PIF, constituted by the varieties of information that have been described, may conjoin through such quantum states of gauge symmetry.

The concept of physical biofields as matrices of energy, information assessment, and communication that governs biological molecular processes is not new (Kafatos et al., 2015; Fels, 2018) Muehsam et al. (2015) had defined the field concept as "an organizing principle for the dynamic information flow that regulates biological function and homeostasis." (p.42.) In a similar manner, viewed as a PIF, an information architecture encompasses 'classical' data points, their antipodes, adjacents, and informational spaces. All might have a direct connection or lesser degree of attachment to one another through non-local correlations. Since all of these, together, represent the summation of inputs available to any living organism, and each can only be accessed through a biological medium or with a time delay, they all represent sources of informational ambiguities. The non-local correlations that exist through these attachments can be identified as sources for subliminal consciousness, intuition and creativity. Through these, information space-time is being interrogated by both observational choices based on classical realism and hidden non-localities that all interrelate. In such circumstances, creativity becomes a temporary attachment to quantum non-local correlations as a form of informational entanglement. Perhaps this accounts for the fact that creativity is a 'spontaneous' burst and cannot be forced. Thus, the cusp of creativity as higher intelligence is in the further exploration of implicates as a function of informational space-time with its augmented 'veiled' non-localities. As any such capacity is embedded within basal self-reference, it can then be assumed that it is available to all living organisms, each according to its limits. Humans simply manifest these attachments in our own idiosyncratic manner.

To summarize the foregoing in brief, biology exists within multiple overlapping aspects of information space-time, in which every living organism attaches to information space through both overt and cryptic means. It is through both these means that self-referential information achieves its 'roundness' by direct assessment, adjacents, antipodals, interstices, non-localities and anticipated information that does not arrive. The direct assessment of information forms our 'classical' reality. Antipodes, absentials and adjacents can then be placed into quantum terms as simultaneous superimposed aspects of 'self' that are not part of our 'active' experience, but still part of an entire attachment to information space-time. Each observer can settle the same information cue into different information resolutions. In such circumstances, consciousness is the simultaneous expression, suppression, and mixture of these overlapping modes. Together, they derive from the organism's PIF that is interpreted through that organism's informational architecture that can then form subjective phenomenal experientiality for that particular organism.

The 'Senome concept' has been proposed as an interface between transmitted energies that constitute sensory information and the cellular mechanisms that permit its physiological reactions and modes of communication (Baluska and Miller, 2018). The senome represents the combined totality of sensory inputs for any organism that can integrate with the genome, epigenome, and other aspects of cellular activity or memory. At the cellular level, the senome has its epicenter at the level of the plasma membrane. The sensome and its inputs provide the vital intercessory linkages between sensory inputs, cellular memory, and biological expression that maintain homeostasis and assure organismal-environmental complementarity. It is the senome that "translates physical signals from the outside world into the physico-chemical language of cells" (Baluska and Miller, 2018). Through

interrogation of the environment, the senome can be considered a cell-wide cellular sensory organ that serves as the functioning conduit between the self-referential centrality of the cell, its individual PIF, its underlying informational architecture and actual biological expression.

With this as background, it is proposed that self-referential awareness, as a whole cell phenomenon, achieves a phenotype unique to each type of organism, of which the senome is a crucial participating aspect. The concept of a self-aware phenotype has been previously proposed as an interaction between genes and the environment (Rochat, 2011). It has also been previously argued that the qualia of any organism should be considered a phenotype based on it being an example of a structural or behavioral trait that interacts with the environment based on prefigured memory (O'Doherty, 2013). In that frame, consciousness is the signal detection of stimuli from the outward environment as it impacts stored experiences of past events. Rees (2013) noted that despite many variations in the extent or intensity of experiences between individuals, a significant proportion of conscious experience is heritable. Correspondingly, it is suggested that consciousness can subsume a conscious phenotype that has adaptive significance.

By definition, the characteristic state at which an organism maintains itself is its most probable state. It is possible to construe the coordinated and preferred compendium of sensory physiology, anatomy, and sensorimotor patterns that constitutes the preferential state of an organism as a form of phenotype. The specific attribute of that conscious phenotype would be the set of boundary parameters that permits the minimization of variational free-energy to maintain homeostatic equipoise. Any unanticipated external environmental perturbation that places an organism beyond its upper boundary of surprisal (a low probability of prediction) can be considered a stressful deviation of homeostasis and variational free energy. As the minimization of variational free-energy directly relates to the suppression of surprise (improved prediction), it can therefore be considered a specific dynamic that encourages that phenotype. It can be considered that any attempt to consistently attain a preferred state (the lowest probability of surprise and stress) is a form of niche construction. This is especially so when that state is sought in multi-cellular terms, which is a consistent biological reality. *Thus, it can be asserted that the collective cellular effort towards resolving uncertainty and minimizing surprise is a form of niche construction of a conscious phenotype.* These same set of principles have been applied to all phenotypes (Constant et al., 2018). It would be reasonable to proffer that this same principle could equally well relate to a conscious phenotype.

It is certainly clear that species experience spatial reality and time differently (Healy et al., 2013; Reddy and Pereira, 2016). Therefore, it is proposed that this unique combination of senomic self-referential experientiality and the precise pattern of those connections to cognitive action reflect an organism wide conscious phenotype. Each such phenotype is utilized towards the minimization of variational free-energy in a unique manner by each type of organism. As every macroorganism is its own exclusive constellation of collective co-linked and co-dependent cellular ecologies, phenomenal experientiality for each organism is a derivative of its conscious phenotype and its variation within the delimiting proscriptions of the species. Thus, the conscious phenotype of each species, and then, too, each individual within that species, achieves phenomenal experientiality in its own idiosyncratic manner, each with its own privileges and limitations, each through its own boundary limits of variational free-energy.

As a further advantage of this framework, a more realistic model of multicellular aggregated self-reference pertaining to holobionts can be offered. When holobionts are properly considered a co-aligned series of networked multispecies cellular ecologies, the

informational architectures of each of the cellular participants combine at the level of the local ecology and then further summate as an overlapping and mutualistic information network. This combination is best considered an aggregated informational motif (Miller, 2017). However, even when so combined, each cellular participant is still attached to its own self-referential information space-time matrix. Therefore, the causal power of 'self' at the level of the entire holobiont is a complex networked integration at multiple spatio-temporal levels as they aggregate. Each ecological level has its own variety of participants accessing information space in both individual and complementary ways. In this manner, multiples of EI^* are achieved, level by level, as each ecological unit within any holobiont measures its own information space-time within its own constraints (Hoel et al., 2016). When so considered, levels of consciousness can be measured as functions of the activation of specific cells or as entire ecological units by a specific stimulus. Obviously, this also becomes a function of the time available for processing and would naturally be exclusive to each set of conjoining cells (Cleeremans and Sarrazin, 2007). For example, activity in the lateral fronto-parietal area of the brain seems to have both an augmenting and restrictive effect on the conscious perception of somatosensory stimuli (Boly et al., 2013).

Therefore, basal self-reference, which is embodied in every cell, achieves macro consciousness in its own idiosyncratic manner for every species, and even each holobionic individual within that species boundary. Each is its own unique collection of nested mixed cellular-microbial ecologies. Each consciousness is different, and each conscious phenotype is different, just as is every other phenotypic aspect of a species. Age related differences in cognitive abilities reduce to differences in growth and development at the level of cellular ecologies as they mature to adult form as a holobiont. In largest measure, in cellular terms, this can now be considered a measurable function of the degree of entanglement expressed as forms of or intensity of complementarity. In turn, cognitive loss is the breakdown of individual cellular capacities, groups of cells as ecologies and their entangled connections. Thus, conscious phenotype is not only related to the brain or nervous tissue, but can be properly understood as a whole body phenomenon (Fuchs, 2012).

3. Self-organization and the cell

Complexity theories assume that there are self-organizing properties in the universe by which degrees of order arise and contribute to the emergence of life and its evolution (Kauffman, 1992). Investigations into such self-organizing tendencies have concentrated on complex organizations demonstrating consistent non-linear behaviors as adaptive living systems (Anderson, 1999). Within that framework, four key elements have been identified: a) active agents, b) energy that can be imported to sustain self-organizing networks, c) co-evolution to the limits of chaos, d) systematic evolution based on recombination. It is offered that all of those basic requirements are met by self-referential cells with genetic and molecular memory. Clearly, cells are active agents. They acquire and dissipate energy. Cells link in extended self-organizing networks but are subject to substantial intermittent instabilities. This is the means through which macroorganisms are achieved. And lastly, they enact that product through the recombination of information through abundant communication. Through these means, cells entangle and recombine in unique aggregates as species (Miller, 2013, 2016a). The direction of those complex entanglements is consistently modified as self-organizing solutions applied towards countering environmental impositions (Anderson, 1999). Thus, it is argued that the basic cell meets the requirements of inherent self-organization as framed through modern

complexity theory. Most importantly, it is further asserted that the foundation of this level of self-organization is through the self-referential assessment and deployment of information. Therefore, it can be directly proposed that self-reference is the basis of the living circumstance (Miller, 2016a, 2017; Miller and Torday, 2018). It has been advanced that any self-organizing living system requires the co-emergence of autopoietic systems as its means of recursive re-creation (Maturana and Varela, 1980; Mingers, 1991).

Such autopoietic systems have been defined by Bourguine and Stewart (2004) as, “a network of processes that produces the components that reproduce the network, and that also regulates the boundary conditions necessary for its ongoing existence as a network” (p. 327). Certainly, these qualities are met by any cell. Each can regulate its boundary conditions within homeostatic limits and contains the means for its own reproduction. Therefore, cells are autopoietic systems. Since any recursive cellular re-creation is directed to the defense of its own self-identity, it becomes a straightforward derivative that it is self-reference that is the essence of autopoiesis as it is demonstrated in living systems. The comments of Locker (1981) about the relationship between consciousness and autopoiesis provide support, “When hidden assumptions are made explicit something very astounding may be revealed: apparently the relationship of autopoiesis to self-reference and to consciousness does not occur because of the “emergence” of consciousness due to the evolution and increase of complexity of autopoietic systems (e.g., the brain) – construed even as an epiphenomenon (Varela, 1971) – but rather for an opposite reason, namely, that the self-evident comprehension of ourselves has to precede the contrivance of autopoietic systems.” (p.3). Differently put, the instantiation of self-reference precedes biological self-organization. There need be no mystery here. Self-organization is time-related function. In the living state, such systematization requires memory. Obviously, there is a history of prior states along any path towards self-organization. Therefore, for the initiation of the living state as a self-organizing system, which has a memory requirement, self-reference has to be its initiating factor. Only self-reference can provide that initiating memory capacity. That can only come from pre-existing memory which it acquires at its instantiation through its attachment to physical information space-time. This is what permits the discrimination of ‘is’ as opposed to ‘other’, upon which self-reference depends. Both self-referential awareness and self-organization require memory. Self-reference achieves that through its entangled attachment to information space-time. As a necessary correlate then, living self-organization is achieved through self-reference.

With this as prelude, it can be asserted that the basic cell is both the embodiment of ‘self’ and also a repository of information space-time memory. This should not be controversial insofar as any process of homeostasis must have a component of active memory to assess any particular status as a distinction to a prior one. It has previously been argued that cellular physiology as active homeostasis is a self-referential cognitive function (Takada and Jameson, 2009; Miller, 2016a, 2016b; 2017; Torday and Miller, 2016b; Miller and Torday, 2018). Any self-awareness is dependent on continuous physiological activity and the information assessment tools and memory that permit it. Within any quantum frame, the dissipation of energy as work, generated heat or communication can be viewed in terms of the deconstruction or emergence of coherences. Such coherences are necessary to maintain a preferential cellular state as homeostatic balance. In cellular terms, this heat dissipation can be considered as a series of downhill thermodynamic gradients whose path is directed towards the optimization of variational free energy as a function of prediction and the suppression of surprise (Aledo and del Valle, 2004; Friston et al., 2006; Torday and Miller, 2016b). Importantly, such actions are all

a function of information and memory. Therefore, the self-referential cell, as the foundation of biological self-organization, optimizes variational free energy and information through embedded memory.

It follows then that the multicellular form must be a collective means of optimizing all three of these requisites. As the optimization of energy and information is dependent upon cellular memory, it would be expected that the multicellular form permits the memory of the basic cell to be leveraged. It is proposed that the collective cellular form not only maximizes EI^* , but does so by leveraging cellular memory systems through shared information space-time. In effect, this is a form of networking in parallel with cellular information processors. Human engineers utilize this principle to improve computer performance in data analysis. Thus, it is argued that there is a natural impetus for self-referential self-organization in terms of energy utilization, the assessment of information, and the maximization of cellular memory. While the need for efficient dissipation of energy is readily apparent, there is also a less obvious requirement for efficient energy storage in any self-organizing system. Memory is one of its reciprocal forms. As Mae-Wan Ho (1998) had indicated, stored energy is dependent on the ‘space-time structure of the system’. What matters is the complete spectrum of the energy that can be stored or depleted for work that enables self-organizing biological systems (Ho, 1998). EI^* therefore represents combined aspects of information. It is an improvement in the quality of information that is usable for immediate action, information that has been measured as being serviceable in real-time and also stored information as embedded memory. No single memory system is without limits. Thus, the cellular proclivity to maximize the use of all forms of energy (as work, information, variational free energy or stored memory) are all aspects of critical self-organizing impulses driving towards multicellularity and mutualistic cellular behaviors.

4. The scope of cellular self-reference

It can be asserted that there are three entwined elements to the enigma of ‘self’. A self-referential organism must ‘know that it knows’. An aware organism grasps that it exists separately from the environment and might make contingent choices within it. Yet, self-reference is clearly more than that. It is also required that organisms ‘know that others know’. And further, there must be some understanding that others like themselves ‘know in self-similar patterns’. It is asserted all three elements of self-reference are implicit to multicellularity and form the basis for the mutualistic assessment of information either within biofilms or among holobionts.

From the foregoing, it is argued that the basic cell should be considered such a tripartite amalgam of ‘self’. Clearly, cells are aware, anticipate and can predict (Saigusa et al., 2008; Nakagaki et al., 2000; Schumann and Adamatzky, 2011; Bonifaci et al., 2012). The collective form of life, even at the level of prokaryotic biofilms, requires anticipation and prediction to support the trading of resources and specializations that enable it to perpetuate (Hellingwerf, 2005; Ben-Jacob and Levine, 2006; Ben-Jacob, 2009; Ford, 2004, 2009; 2017; Xavier et al., 2011; Miller and Torday, 2018). Yet, each of the cellular participants are reaching towards their own preferential homeostatic states (Miller, 2013; 2016a, 2017; Miller and Torday, 2018). Therefore, for cells, the collaborative associations that dominate life are predictions by any cellular participant towards an anticipated state of preference. It can be asserted that any mutualistic collective association can only devolve if there is some expectation on the part of each participant that contingent fellow participants have mutualized phenomenal experiences that direct towards preferential states in a self-similar manner, even if

such states are not identical. Since there is a cost to any association and particularly any failed one, then, any such association represents the self-referential cellular prediction that it is worth the risk. In order to 'know' that its attachment to any cellular collective is in its best interest, the individual cell must measure. Therefore, in so doing and in the expectation of reciprocation, it must have mechanisms to anticipate that other cells also 'know' as much as they do, and might measure in a generally similar manner. This is not conjectural. Any collective cellular form must be based within this expectational matrix in which phenomenal experientiality is generally shared. It can be asserted that it is the 'knowing' of self-similarity of how cells of like kind will experience information that permits the collective form of life.

As already noted, any association is a prediction that includes 'knowing' that another corresponding participant knows (would similarly predict) to reach a consensual state of preference. When this is acceded, then, 'knowing that you know' follows as a necessary implicit. It can be effectively argued that 'knowing that others know' can only flow from 'knowing that you know'. No logical argument might defend the inverse. Therefore, the mutualism that is everywhere observable across biology is direct evidence that individual phenomenal experience is fully invested at the individual cellular level and that such a level of experientiality includes knowing self, knowing that others do also (will respond and reciprocate), and knowing that the experiences of others has some direct relationship to its own individual experiences (self-similarity). Cellular mutualism and its concordant specializations perforce includes 'knowing' that the inter-organismal terms of the assessment of information has general coherence. Therefore, all elements of tripartite self are requisites to sustain any of the mutualistic collective cellular networks that comprise complex life. It becomes a necessary assumption that each of the individual participants in multicellular collaborative ecologies must be aware of all three of the tripartite particulars that compose 'self'. Through their association, they anticipate that they can arrive at their own state of preference through consensual attachments. All parts of 'self' are required for such an assessment. A necessary codicil thus attaches. The basic cell has subjective phenomenal experientiality as its own proscribed qualia. Thus, the 'hard' problem has its base at the level of the individual cell. It is argued that the genome of the cell is the essential apparatus of that 'hard' problem of subjective experience.

Certainly, it could be countered that cells are only doing what 'feels good', in an automatic homeostatic sense, which does not involve self-awareness. That point of view could be supported if it were not also true that collective cellular life, even at the level of biofilms, includes prediction based upon sharing of resources, the trading of those means, forms of unicellular specializations, and basic computational measurement skills. The collective form includes the anticipation that resources will be shared towards attaining and sustaining individual preferential states. This is the direct aim of self-referential awareness. Its further expression in the collective form could only stem from knowing that others will assist towards that aim and that interests will conjoin. Since the collective form of life has been traced through microfossils to nearly the projected origin of life (Schopf et al., 2018), it can be argued that 'knowing that you know', 'knowing that others know', and 'knowing that like others know in self-similarity' is likely as old as life. Therefore, it is credible to consider this tripartite status as the proper definition of the living state. Consequently, it should be assumed that the entire spectrum of phenomenal experientiality that reposes within the cell should be regarded as the basal core of self-referential cognition and self-identity that further enumerates across evolutionary space-time.

Clearly, cells are not automata and demonstrate self-referential cognition (Ford, 2004, 2009; 2017; Miller, 2013, 2016a; 2016b,

2017; Miller and Torday, 2018). Cells have the ability to make individual and collective choices regarding the specifics of their associations at their scope and scale. Therefore, it is not merely bioactive molecular signaling and cell-cell communications through a variety of biodynamic energetic fields that permit cell aggregation. Instead, it is the characteristic similarities among cells in their self-referential assessments of information that is the operative means. It can be asserted that if individual cells were not self-aware in a similar manner, there would be no cellular associations which are so intimate that apoptosis is one of its features. If that were not so, and instead, there was no recognition of inherent self-similarity, then, there would only be single cells in random distributions like gas molecules in a flask. The fact that the living circumstance of cells is different must center within the self-referential capacities of cells that are similarly constituted. In other words, there is both structural coherence to self-awareness as well as a general organizational invariance (Chalmers, 1995). Indeed, it is argued that it is tripartite basal self-reference that underpins the structural coherence and general organizational invariances of the basic cellular forms. Bioactive processes sustain that self-reference through embedded memory in the crowded active environment of the cell. It has been previously asserted that small sequential decisions uphold life at all scales (Grandpierre et al., 2013). It is further insisted that all such decisions at the cellular level are all derivative of an ample tripartite self-referential state.

5. An integrated approach to self-referential consciousness

A definition of self-reference has its obvious difficulties in an era in which machines portray categorical living properties including the ability to sense and use information, to communicate and to problem-solve. Von Neumann explored this through his theoretical designs of self-reproducing computational cellular automata (Bedau, 2003). Along these same computational lines, it has been argued that life could be productively examined within the framework of information systems that can be interrogated on a mathematical basis (Davies and Walker, 2016). Life might then be modeled as analogous to banks of computer circuitry and cells conceptualized as modules with logical functions. These could link together to process information which can then be refined by natural selection. In this frame, informational computation is the selectable trait. Yet, analogies of life with machines and circuits have their obvious limits and it has been vigorously defended that life is different from physical states (Goldenfeld and Woese, 2011).

Given these differences, it might be expected that understanding the origin of life might offer some clarifications. The instantiation of self-referential awareness as the origin of life has been attributed to a derivative of the thermodynamic scale as a phase transition that operates as a state function (Eigen, 2013; Miller, 2016a, 2017). Eigen (2013) considered that specific phase transitions that had both entropic and semantic qualities emerged from the reproduction and transmission of information at a complexity threshold. Computational research has shown that the optimal conditions for information storage and transmission can be identified as residing in the vicinity of such phase transitions (Langton, 1990). Others have also considered the emergence of life as a first-order phase transitions occurring during periods of environmental shifts (Mathis et al., 2017). At crucial transitional periods, selection might have driven an explosive growth of replicators that altered the degree to which information is shared between the outer environment and a growing system of replicators. In this framework, the origin of life could be understood as the source of information that could replicate and can be placed in a mathematical context (Adami, 2016). If so, then entropy can be regarded as

primordial information in probabilistic zones of preferential concentrations of essential monomers that could actuate potential candidates for biochemistry such as carboxylic acids.

It has also been proposed that life is artifact-making akin to manufacturing (Barbieri, 2016). Within that framework, genes and proteins could be regarded as artifacts produced by molecular machines which are dependent upon instructional code. In such a case, information is fundamental, but cannot be strictly computed within the context of its living state until it acquires a 'nominal' character. This necessitates an 'observable'. Therefore, even within this machine-like frame, life cannot be regarded as just simple chemistry or even extremely complex chemistry. Even in this instance, there is a need for information to be accessed, evaluated and deployed through outward observables. Therefore, it can be argued that the living state has an intrinsic difference from computers, even when some molecular processes seem analogous to machine-like feedback circuits. A machine should not qualify as a true observer since 'observer' status in the living state is defined through knowing ambiguity.

In view of those obvious differences, some propose that 'self' has to be considered an irreducible state of awareness that is fundamental to the universe (Davies, 2009; Theise and Kafatos, 2016). Awareness would be the actual cosmic reality with the universe its own subject and observer, thereby privileging information over material form (Theise and Kafatos, 2016). In that speculative view, the cosmos is inherently self-organizing and recursive. Yet even so, there is still a meaningful difference between physical phenomena that self-order, such as crystals, and actual self-organization of the biological kind. While it seems apparent that autopoiesis is an essential aspect of living organisms, it still does not define the living state (Bitbol and Luisi, 2004). The difference is that in the living circumstance, prescriptive information necessitates choice contingencies in which there are many configurables that extend beyond chance probabilities. Biologic self-organization represents a distinct faculty to use symbols as information for purposeful actions towards that living goal (Abel and Trevors, 2006).

As opposed to any larger teleological aim, it is asserted that the identifiable goal of the living circumstance is narrow. It is restricted to the maintenance of homeostasis as its biological expression of preferred self-referential status. It can be directly stated then that life seeks to sustain itself, which can also be equivalently formulated as 'self-reference defends itself.' This is similar for cells as it is for complex multicellular ecologies and for holobionts. Clearly, all such actions are information dependent. Furthermore, the contingent deployment of information is certainly a form of problem-solving. Therefore, a useful reduction ensues. *Self-reference is the self-directed ability to maintain itself by using uncertain information to problem-solve.* Therefore, the essence of self-reference is choice contingency. And further too, those choice contingencies can be alternatively expressed as superimposed ambiguities (implicates in information space-time). And further yet, any deployment from within that framework is a form of contingent prediction from within the qualia of doubt. When so considered, self-referential awareness can rather readily be distinguished from any programmed machine.

From the above, and for any living organism, it becomes clear that self-reference is its basal awareness of its ambiguous circumstances. From this, a further requisite follows. Any such awareness of indefiniteness is based on its sources of information (symbols) and must proceed through its attachment to information space as the source of those ambiguities. Biological information space is inherently equivocal secondary to the degradation of sent or received information due to time, distance, and medium of transmission in the classical sense of information. Further ambiguities arise from antipodal information that might be vaguely sensed. The

scope of information space-time for a living organism can then be codified. It is a matrix of informational cues that constitute sets of implicates which can be organized by information management (pragmatic syntactic rules). From the foregoing, an appropriate conception of 'self' as a living state can be offered. *'Self' is the base system repertoire of an organism that permits its organized attachment to biological information space-time with its implicit uncertainties.* For any organism, its 'further self' is thereby delineated. That is its organized use of information space purposed towards an augmented range of problem-solving as the defense of self in ambiguous circumstances. Phrased with more succinctness, self-reference can be well-defined as the property of 'knowing that information need not be deliberate'.

It can be considered that biological 'self' can be examined as matter-symbol complementarity in which the relationship between the two involves choice and contingency. In those pragmatic and symbolic terms, self-reference can be inferred as closure between dual inter-relating spheres. The first is comprised by material objects and the set of dynamic physical laws under which they are governed, just as with any machine. The other is the deployment of symbols (i.e. bioactive molecules, signaling pathways) commanded through syntactic rules under biological constraints (Pattee, 2012). It is asserted that the specific operative and separating constraint between the living state and even the most complex machines is that self-reference 'knows' the equivocal nature of biological information. This extends beyond any simple range of accuracy, but an understanding of genuine equivocality in which some inputs defy attempts at accurate measurement. Putting the difference directly, unlike machines, the living state includes doubt. *Self-referential subjectivity equals knowing 'doubt' (informational uncertainty in all of its various forms) as its essential qualia.*

Therefore, it can be argued that a useful crux between the living and the non-living lies within the specific manner in which information is sensed and used. This perspective has been advocated for many decades. Van Uexküll had formulated a biosemiotic approach that conceptualized the relationship of an organism with its environment (Tønnessen et al., 2016). The *Umwelt* is the entire informational surround that can be the object of subjective perception. That environment carries a series of 'marks' that are sensed by any organism that prime a series of subsequent effectors. Together, the sensors and effectors become part of a feedback loop that connects the organisms to its immediate environment and, in recursive cycles, to the entirety of nature.

The concept of the 'Senome' updates that framework. The senome is the complete sensory apparatus of an organism including its communication structures and its genetic and non-genomic aspects of molecular memory as connections to the environment (Baluška and Miller, 2018). The senome is that constellation of receptive faculties that interrogates both the outward and inner cellular environment to guide cellular responses that can be directed towards adjustments and adaptations. As an important stipulation, the reason for any set of sensory experiences is the active use of that acquired information for problem solving. The senome is proposed to include an electrome defined as the totality of all self-generated ionic currents of a cell as proposed by De Loof (2016). However, the senome is expected to also encompass biomagnetic, biophotonic and biochemical signaling phenomena (Baluška and Miller, 2018). It naturally follows that all the variety of sources of information used to solve problems via the senome requires organization through an information management system. In the living state, the task of that information management system is the continuous measurement of information to solve problems under conditions of ambiguity. Therefore, a defining attribute of any self-referential organism is an informational management system that permits information measurement, choice and

contingency.

It has previously been advocated that information, once received, becomes a form of constraint that links to communication and work (Deacon, 2011; Miller, 2017; Miller and Torday, 2018). This obligatory interrelationship becomes a reciprocating and recursive self-reinforcing process as natural self-organization based upon the necessary connections of triadic energy-information-communication. This can be better understood through a rough analog to Locard's principle of exchange that has been applied to forensics since the 19th Century (Horswell and Fowler, 2004). Locard adduced that any crime had two particulars: the perpetrator left a non-volitional trace, and reciprocally took away something from the crime scene without necessarily meaning to do so. In the self-referential frame, a similar principle applies to information. Any information that is received is unavoidably linked to work through the process of its reception and assessment. Yet, the energy that is expended through that work, within any shared information space, becomes an obligatory communication to some other receptive entity. This inevitably becomes information to some other self-referential participant. Thus, the information cycle forms an inherent and non-volitional reciprocating triadic function of information-communication-work in the self-referential cellular frame (Miller, 2017; Miller and Torday, 2018). Therefore, the reception of information initiates a cascade of successive alterations of information space-time as the collapse of one set of implicates and the initiation of another as a concurrent alteration within shared information space-time (Miller, 2016a). Perforce, any such settling of one set of implicates by one self-referential entity potentially yields a useful compaction of ambiguity of the larger shared information space-time matrix for other observer/participants. In effect, when it is predicated that all self-referential organisms not only 'know' that they know but that other participants also 'know' in a generally similar manner, the settling of an environmental cue by one self-referential observer/participant becomes relevant to others within that shared information space as one instance of problem-solving by a similar entity. In effect, the bandwidth of ambiguity of general information space with respect to a shared environmental cue has been narrowed by the reception and communication of information by any of the participants in a shared information space. Thus, the self-organizational properties of information are centered within an essential reciprocating triad which impels the collective assessment of environmental cues. It is argued that this is a particular driver of multicellularity.

An important aspect of information that is assessed in a collective manner is that there is no requirement for any of the participants to be absolutely accurate and deferred to on that basis. Joint evaluation of information can be modeled on the basis of Friston's concept of the direction of any organism towards the minimization of variable free energy as a means of improved prediction based on suppression of 'surprisal' (Friston et al., 2006). This same technique is being utilized in robotics and drones. Flight drift represents information degradation for the mapping sensors upon which drones rely. The programmed solution set is to choose flight paths measured as 'least uncertain' based on continuous mapping assessment scans. There is no need to determine which among them is most correct. (Papachristos et al., 2017). It can be argued that this is precisely the manner in which multicellular organisms assess environmental cues. Of further import, such systems are neither entirely random nor completely deterministic. It is simply a delimited range of superimposed probabilities best conceptualized as a restriction of information space-time differences between sender/receivers. In this manner, constraints of ambiguity become a central aspect of causal self-reference. As Forshaw (2016) adroitly notes, "Once causal self-reference is attained, freewill is permissible but not without limitation." (p. 60). In other words, the narrowing

of information space-time through 'least uncertainties' which is required to settle superimposed implicates into biological expression effects an intrinsic limitation to the range of choices that any self-referential organism might make.

With this background, a simplified basic structure for consciousness is offered. In cellular terms, basal self-reference can be framed as the self-aware reception of energy received as information that can be mobilized for cognitive deployment and communication (Miller, 2016a; 2017; Miller and Torday, 2018). This includes knowing equivocality through an attachment to information space-time and knowing that others also know in a similar manner. Implicitly, the coherences and structural organization that permit such knowing imply the presence of a fundamental information management system. From this, a functional and measurable definition of basal self-referential cognition can be offered. Basal self-referential cognition is the summation of the cellular interconnections between the senome of the cell (totality of sensory inputs) and its linked contingent reactions as communication, overt biological expression, or additions to stored memory. *In essence, basal self-reference which defines the living state, can be characterized through its observable and measurable scope and constraints in the cellular form.* Since there are only three perpetual cellular forms (Bacteria, Archaea, and Eukaryota), those faculties that are common to all can be considered to represent a practical minimal yardstick of basal self-reference, and then further, as the *sine qua non* of the living state.

Consciousness can then be seen as an integrative spectrum. At the level of the cell, basal consciousness/self-conscious is all apiece. Its elemental unity is embodied as that tripartite self-referential awareness and its cognitive expression that permits the continuous maintenance of homeostatic equipoise at the cellular level. Even at this minimum, basal cellular self-referential consciousness permits the recognized cognitive cellular attributes of problem-solving, prediction, anticipation, and measuring of equivocal information. Thus, the cellular attributes of self-reference are the proper platform for any further inquiry into any further states of consciousness/self-consciousness along the entire evolutionary scale. It does not answer the question of origin, but argues that consciousness and self-consciousness are always entwined at the level of the cell. All life on this planet is defined by that admixture.

The ubiquity of mutualism across evolutionary space-time indicates that self-reference as experienced by cells is also the requisite path towards an active state of any larger consciousness/self-consciousness that can be directed towards problem-solving. This further consciousness is the heightened knowing of self from other and the further nuanced mutualistic expectation of knowing that others know information in a self-similar manner. Thus, gradations of conscious experience exist according to scale (Reddy, 2017). This perspective is similar to that of Tononi (2004) who argued that consciousness corresponds to the systematic integration of information. In this theory, consciousness can be quantized according to the amount of causal functional information available to the system across integrating subsets of elements. The qualitative level of consciousness thus becomes a reflection of the informational relationships among linked cellular elements. As a proxy, this can be considered on the basis of a measured assessment of available EI*, as information that permits an organized system to perform non-random actions. Within this frame, conscious phenomenal experientiality for any macroorganism is the summation of the self-referential awareness for that particular collective cellular organism. This includes the individualized, layered and combined sensory apparatuses of the totality of its constituent cells as they subsume an aggregate emergent quality. In this frame, increased cognitive ability denotes the enhanced informational measuring capacity that permits an organism to discriminate

among sensory inputs either towards immediate deployment, as information that might be used for future biological action, or information to be ignored. In effect, all of the latter can be seen as less noise in the system through a greater repertoire of valid informational inputs.

Therefore, when cells combine to improve information quality, 'higher' levels of consciousness and more abstract types of self-consciousness/introspection can emerge as an enhanced cognitive capacity to problem-solve environmental stresses, through nuanced anticipation and prediction. This also becomes measurable as the ability to discriminate smaller differences between a variety of types of inputs or to become sensitive to information in a novel manner compared to the basic cell. Within this context, 'higher' levels of cognition importantly represent the ability to postpone the settling of a range of superimposed implicates even when a potential solution is sensed compared to any basic cell. This is the realm of abstraction and creativity which we deem as greater intelligence. Thus, all aspects and varieties of consciousness within macroorganisms are the result of this concatenation off a cellular base. Fuller consciousness is a collective augmentation of basal cellular self-referential cognition in idiosyncratic patterns that arise through the multicellular, multispecies networking which characterizes the entangled form of holobionic life.

Since the basal aliquot of consciousness/self-consciousness is invested within the cell, then the active means for its suppression or adjustment at all scopes and scales should be similar. When placed in this frame, several disparate issues of consciousness are reconciled. It would therefore be expected that the exposure of bacteria to the volatile anesthetics isoflurane and sevoflurane significantly change their behavior, particularly pertaining to bio-film formation (Chamberlain et al., 2017). The finding that slime mold, *Physarum polycephalum*, meets the criteria for minimal cognition would not have been surprising (Vallverdú et al., 2018). It would be anticipated that plants exhibit sensing patterns and memory. Nor would it be deemed remarkable that their own significant temporary and selective responses to anesthetics would be interpreted as forms of conscious intelligence (Calvo and Keijzer, 2011; Yokawa et al., 2017). Even for ourselves, it is now well accepted that gut microbes represent a form of collective consciousness that influences 'sub-conscious' human cognitive function and behavior (Dinan et al., 2015). This would be expected, since cellular microbes are also self-aware agents. Both, sentience and consciousness have recently been proposed as fundamental properties of cellular life emerging with the first cellular forms on our planet functioning as a bioactive expression of cellular homeostatic drive in apposition to cellular stresses (Miller, 2016, 2017; Miller and Torday, 2018; Reber, 2018; Baluška and Reber, 2018). Although the exact physical means by which sentience and consciousness at the cellular level proceeds is unknown, those cellular structures that have been implicated in its enactment include excitable membranes, the dynamic cytoskeleton and flexible proteins (Hameroff and Penrose, 2014; De Loof, 2016; Baluška and Reber, 2018).

In the past, it has been asserted that individual self might be explained either by the genome, the brain or the immune system (Rees et al., 2018). Since it is now known that our microbial partners mediate our adaptive immune system, supply substantial components of serotonin and other brain chemicals, and contribute to gene functions, a shift must occur (Ridaura and Belkaid, 2015). As holobionts, our consciousness, cognition and intelligence is a consensual 'we' that includes our critical microbial fraction with its own substantial impacts. As within every aspect of multicellular biology, there is no level of absolute privileged causation (Noble, 2015).

All this yields to a compact notion of consciousness. For any

macroorganism, it is the product of its entangled constitutive cells. And crucially, since the constituents of each holobionic macro-organism is different, each is its own delimited expression of self-referential consciousness. Any understanding of consciousness becomes a cellular interrogation from its base through to its emergent manifestations. Therefore, just as understanding human metabolism requires the evaluation of the entanglement between our innate cells and our microbiome, it is the same for our human behavior and consciousness phenotype.

Indeed, given these findings, it might even be considered that the search for a 'higher' consciousness may in fact represent an inward interrogation. It is possible that states of higher consciousness actually reflect an elemental connection with raw cellular self, neither 'less' nor 'more', but experienced as different, revealing and novel. In this manner, the search for 'inner peace', gains new meaning as an elemental encounter with cellular 'self'.

6. Self-referential information in evolutionary development

In all biological systems, information and its communication precedes action (Trewavas and Baluška, 2011; Torday and Rehan, 2012; De Loof, 2015, 2016; Miller, 2016a, 2017; Miller and Torday, 2018). Implicitly too, any explicit deployment of information by a self-referential entity is a measuring phenomenon. Therefore, as information antecedes selection, then measuring has primacy as it determines the outputs that can be subject to environmental selection (Miller, 2016a, 2017; Miller and Torday, 2017, 2018). Necessarily then, selection can now be properly appraised as a post-facto filter of self-referential cellular measurement. Yet, any measurement through self-reference is itself a dependent function of self-referential information management. It follows that biology is best regarded as a specific kind of self-referential information management system (Miller, 2017; Miller and Torday, 2018). This is as true for holobionts as for individual cells. Thus, in all circumstances, the sensing of information, its measured assessment and its communication are the wellsprings of biological activity. Cellular governance is therefore exerted through this faculty and the manner by which any overarching information architecture exerts its constraints (Marijuán, 2015, 2017; Miller, 2016a, 2017; Walker and Davies, 2016; Miller and Torday, 2018).

It has been previously noted that both physiology and phenotype are properly understood as another form of information management (Miller, 2017). Self-referential self-organization is directed towards maintaining homeostasis through thermodynamically efficient pathways and optimized energy dissipation (Skene, 2015). Obviously, this also requires the efficient use of information. Through reciprocating action among the constituents of any multicellular organization, physiology and phenotype emerge as reciprocating function and form (Baverstock and Rönkkö, 2014). At all times, self-referential cell-cell interactions as physiology and phenotype are directed towards the maximization of EI* and the minimization of variational free energy to optimize predictive value (Friston et al., 2006; Miller, 2016a, 2017; Miller and Torday, 2018).

Therefore, the evolution of physiology and phenotype can now be evaluated as the self-referential use of information through collective nomenclature (shared information space-time) and rules of usage. A comprehensive information management system that organizes sensed information and its further communication is therefore requisite. Since any information management system entails a measuring apparatus, as an alternative to concentrating on descriptive physiology or phenotype, evolution can be explored as the process of how information is measured by self-referential cells, either as individuals or in the dominant collective form.

It has been suggested that biology can be best understood as a summation of biocommunication (Torday and Rehan, 2012;

Witzany and Baluška, 2015; De Loof, 2015, 2016, 2017; Miller, 2016a, 2017, 2018). In such an active frame, cellular life does not dwindle into artifact-making or selection-biased default. Evolution is rooted within cognitive senders and receivers that collaborate in multi-cellular networks to improve energy efficiency and the content, quantity and quality of measured information. This is achieved through ubiquitous cell-cell communication (Bassler, 2002; Ben -Jacob et al., 2004; Baluška et al., 2006; Torday and Rehan, 2012; Witzany and Baluška, 2015; De Loof, 2015, 2016, 2017; Miller, 2016a, 2017, 2018). At successive levels, all organisms represent self-referential living solutions arbitrating ranges of environmental flux. The physiology and phenotypes of the multi-cellular form are those consensual solutions.

It has previously been argued that phenotype is a tool by which the eukaryotic unicellular form explores the environment to assure its continuous organismal-environmental complementarity (Miller, 2016a, 2017; Torday and Miller, 2016a, 2016c; Miller and Torday, 2017, 2018). When self-referential awareness is viewed as the basal building block of any further conscious phenotype, it becomes another tool of environmental exploration for the benefit of sustaining self-identity.

Every macroorganism is obliged to recapitulate though a eukaryotic unicellular phase from which the entire adult re-elaborates. As such, it is a direct precondition that all requirements for all the eventual adult phenotypes are as embedded within the bauplan of that eukaryotic zygote. By default then, this must also apply to any applicable conscious phenotype. It has already been defended that evolution is always about the continuous defense and perpetuation of the three essential cellular forms (Bacteria, Archaea, Eukaryota) (Miller and Torday, 2018). The eukaryotic macroorganic elaboration of adult phenotypes is the means by which environmental inputs return to the recapitulating and fundamental eukaryotic unicell (Torday and Miller, 2016c,d; Miller, 2016a, 2017). It follows then that eukaryotic evolution is now best understood as the continuous defense of eukaryotic self-referential identity. It then further follows that the macro elaboration of conscious phenotype and any of its extensions are its tools.

The concept of extended phenotype is not new (Dawkins, 2016.) This has been typically ascribed to genes. From that theorized base, the behavior of an organism is not necessarily for the direct welfare of any specific organism but is, instead, for the 'good' of the genes (Laland, 2004). In this context, 'selfish' genes act in their own defense in the context of populations. But not all have willingly accepted the typical narrative of extended phenotype. Turner (2004) had offered a critical assessment that the extended phenotype concept was inapt if applied to genes and should instead be regarded as an aspect of extended physiology. Since it is now clear that genes are agents of the cell as a part of a larger cellular self-referential toolkit, it is instead proposed that self-referential awareness is the proper locus of that 'selfish' impulse. Genes are its essential tools and all extended phenotypes are purposed towards the defense of self-referential identity through physiological and immunological means (Miller, 2016a, 2017).

When consciousness is placed in this context, the concept of extended phenotype can be further rationalized. For example, some pathogens can manipulate host behavior by alterations in genetic expression to assist in its life cycle. The so-called zombie ant fungus, *Ophiocordyceps unilateralis sensu lato*, manipulates its carpenter ant host, *Camponotus castaneus*, in a specific moment in the parasite's life cycle (Fredericksen et al., 2017). Highly coordinated behavioral control of the host by the parasite is affected by changes in host gene expression and atrophy of selective host muscles. A strikingly similar strategy is demonstrated by the *Drosophila* fungal pathogen, *Entomophthora muscae*, that invades the fly's brain and forces it into a position where fungal spores can be forcibly ejected from

its abdomen (Elya et al., 2017). In both instances, the ability of the pathogen to manipulate the host to assure its life cycle has been considered examples of extended phenotype on a genetic basis. However, in circumstances in which all of the participants are not automata, the particular phenotype that is being extended is the 'consciousness' of the parasite at the expense of the host. It is the former that has choice contingencies which is being extended by one organism, and expressed within another. Its aim is to assist the reproduction of the parasite's eukaryotic unicellular self in the furtherance of its own long-term self-identity. The tools of this further expression are the genes, muscles and bodies of the parasitized host organism. Yet, even those fungal parasites, as eukaryotes, yield to unicellular recapitulation. Therefore, its adult life cycle, in all its myriad manifestations, including its use of extended phenotype, is still an agency of the primacy of self-referential eukaryotic unicellular perpetuation.

The frame of an extended conscious phenotype melds quite well with the concepts of extended mind promulgated by Clark and Chalmers (1998). In extended mind theory, the use of computers, memory, or communication devices, as well as other aspects of the external environment, represent extensions of the cognitive state. Clark and Chalmers (1998) had opined that larger consciousness might be considered an extension of a more basic 'self'. Then, any physical device that enhances human consciousness as expanded sensory experientiality, calculation, measurement, memory or any tool employed by any animal to problem-solve, becomes an extension of its consciousness. This concept can be applied to conscious phenotype which has its own capacity for extension. It operates within the same principles that apply to other types of phenotype, such as a screw driver or throwing stick amplifying the phenotypic capacity of human arm muscles. Japyassú and Laland (2017) have represented a spider web as an example of this type of extended cognition. The spider gains significant information through its web that yields an improvement in its ability to capture prey and its connection to the environment. They note that this concept crucially differs from Dawkin's conception of extended phenotype. Extended cognition is meant to signify an amplification of reciprocal causation between the organism and the environment through modification. Therefore, it is more akin to a niche construction. The concept of conscious phenotype resolves the differences. By definition, conscious phenotype is the result of whole body processes that exist beyond any central cognitive brain or central nervous system approach. It therefore also applies to any environmental influences. Environmental stresses affect the range or levels of consciousness just as leg muscles are affected by extremes of ambient temperature. Therefore, extended mind, extended cognition and extended phenotype as genetic selfishness can all be unified by the concept of conscious phenotype. All phenotypes represent tools of the self-referential exploration of information space-time that can be directed towards problem-solving. Thus, the adaptive value of an extended conscious phenotype over evolutionary space-time is clear. The same concept represents a further justification for the fact that all multicellular eukaryotes are obligatory holobionts. The collective cellular and multispecies assessment of information is an extension and maximization of conscious phenotype for each individual participant as its best means of exploring information space-time. It can even be proposed that all life can be considered a fractal reiterative process of extended conscious phenotype. Endosymbiosis can be examined as such an example. Eukaryota themselves can be viewed as a collective form of life based on endosymbiosis of indwelling prokaryotes as mitochondria that have maintained their own genetic complement and their own idiosyncratic self-referential consciousness (Ford, 2017). If so, then, all holobionts as vast co-linked multispecies cellular ecologies are alternative manifestations of

extended self-referential conscious phenotype whose point of origin is always centered by the obligatory recapitulation of the fundamental eukaryotic unicell.

The same can be considered for collective mind in group cognition (Tollefsen, 2006; Theiner et al., 2010). Collective consciousness is just another tool to explore information space-time. Whether the instance is an insect swarm or human mob behavior, all the individual participants remain separate and self-identifiable participants even within the enlarged collective phenotype of group thought. All such phenomena are further extensions of conscious phenotype as manifested by that particular species.

It has been previously advanced that self-reference is best regarded as a spontaneous state function as a derivative of thermodynamics in which non-random out of equilibrium processes could be sustained within bioactive boundaries (Miller, 2016a). From that instantiating moment forward, evolution is clarified as the elaboration of communication and problem-solving in the purposeful use of information that serves 'self' as a timeless continuity. (De Loof, 2015, 2016; 2017; Miller, 2016a, 2017; Miller and Torday, 2018). Ulanowicz (2011) points out that Darwin viewed evolution as process. It was Fisher and Wright in their evolutionary synthesis that particularly emphasized objects and mechanisms within competitive selection. It is not surprising that such an attitude was a comfortable assumption in a Post-Victorian era. However, contemporary biology has determined that our dynamical biological system is clearly based within a framework of ecologies and mutualism (Ulanowicz, 2011b; Miller, 2016, 2017; Miller and Torday, 2018). Such ecosystems are enabled through cellular assessment, measurement and mutual constraints directed towards attaining and sustaining preferential states. All of this proceeds through a fundamental information cycle from which biological expression derives (Miller, 2017). Thus, selection operates post-facto of these processes. Importantly, successful mixed cellular/microbial ecologies, as the dominant form of life, are not the results of simple default selection based solely on stochastic processes. Rather, they are the results of the purposive actions of mixed cellular participants and quite possibly of their co-aligned viruses (Gilbert, 2014; Miller, 2016a, 2017). Thus, life and its evolution are verbs (De Loof, 2015, 2017; Miller, 2016a; 2017; Miller and Torday, 2018). And, the pertinent noun is 'self-reference'. It is therefore argued that evolution is the continuous defense of instantiated self-reference and its further enumerations, whether expressed at the unicellular level or as holobionts. Our particular human experience of that self-reference is our idiosyncratic collective layered variety of that fundamental endowment.

7. Consciousness as sense – self-awareness at different levels of biological complexity

The origin of fundamental awareness may never be known. However, it is reasonable to suggest that the origin of self-reference must have occurred in one of two ways. Either it began as an orthogonal of the physical world and the thermodynamic parameters that characterize it, or it began at the Singularity as a monistic state from the universal expansion forward. Both propositions can be defended (Whitehead, 1929; de Chardin, 1959; Morowitz, 2004; Eigen, 2013; Theise and Kafatos, 2013a; Kafatos, 2015; Miller, 2016a, 2017; Theise and Kafatos, 2016; Torday and Miller, 2018). It has been proposed that however instantiated, life should be a dynamic that could be measured as the combination of accident and necessity governed by potentially identifiable forms of 'law-like evolutionary convergence' (Walker and Davies, 2016.). Yet, any attempt to find that regularity through analogies of life as circuitry or as a machine would be misplaced (Witzany and Baluška, 2012). It

is instead argued that the appropriate convergence begins with the identifiable ground state of the measurable scope of self-referential awareness as embodied within cells (Reber, 2018; Baluška and Reber, 2018). All life flows from this practical minimum, and there is nothing living that does not consist of or operate from within that specific archetype.

In asserting the difference between the 'easy' and 'hard' problems of consciousness, Chalmers (1995) assumed that only some organisms are subjects of experience. However, with over twenty years of further research, it is now known that all living organisms, within their own limits, are experiential with attendant ambiguities according to scope (Mashour and Alkire, 2013; Boly et al., 2013; Klein and Barron, 2016; Miller, 2016a, 2017; Baluška and Miller, 2018). Thus, any arbitrary divide between the 'easy' and 'hard' problems of consciousness requires reconsideration (Dennett, 1996; Hodgson, 1996; Theise and Kafatos, 2016). It can be proposed that the 'easy' part of consciousness might be that aspect of 'self' that links to classical realism as the transfer of energy and biomolecules along known pathways. This can be alternatively considered as that information that is directly assessed within a dimensional information matrix. The 'hard' part can then be framed as the interstices of non-locality, quantum entanglement, the assessment of antipodal drift, information on the adjacents, or anticipated information not received. All of these have not been amenable to conventional measurements. Yet, both are aspects of consciousness. In effect then, consciousness represents the continuous collapse of portions of information space in which any participating 'living' observer only actively senses a part, but nonetheless experiences the collapse of information-space as a 'whole'. Thus, consciousness is the conjoining of the conscious ready assessment of information and a broad range of subliminal self-consciousness based on adjacents, absentials, veiled non-localities and apophysics in informational space-time (Deacon, 2011; Kafatos and Kak, 2015; Marijuán et al., 2017). Even so, the division between an 'easy' and a 'hard' problem remains useful. One aspect is more difficult to interrogate than the other. Yet, it is important to place them both as companionate expressions of essential self-referential cellular awareness. Both consciousness and self-consciousness are aspects of those delimited self-referential capacities that define cellular life (Reber, 2018; Baluška and Reber, 2018). When examined in detail within that cellular context, both might be measurable. It is directly asserted that since every cell has its own proscribed capacity to access both apodictic and antipodal-information, both comprise cellular phenomenal experientiality. The instantiation of self-referential awareness as the attachment to informational space-time is the commencement of that experientiality since it is the birth of informational ambiguity and the commencement of the living condition. Thus, it is argued that the 'easy' and 'hard' problems are only differing manifestations of the same self-referential fundamental essence that is embodied within all cells. The issue of whether consciousness/self-consciousness is divisible to any particular sub-component cellular part becomes a separate investigation.

Although it has been previously maintained that analogies between computer circuitry and living systems are fraught, there is still one serviceable analogy that might be offered. No computer is understood either through its hardware or software apart from its operating system. The complex cell requires its own operating system which utilizes a, "highly parallel distributed control system to maintain its organization and regulate its dynamical operation in the face of both internal and external changes." (Dougherty and Bittner, 2010, p. 221). Therefore, both the 'easy' and 'hard' part of consciousness must have a relationship to that aspect of the information management apparatus of the cell that governs its attachment to information space-time. Thus, the proper focus for

investigation of consciousness is an examination of the dynamics of the cell's attachment to information space-time.

Within that context of information management, multicellular organisms are linkages of the informational architectures of each of the individual self-referential participants. In that case, it is proposed that any attempt to dissect our consciousness through an examination of being clinically 'unconscious', as typically appraised, is wrong-footed (Kastrup, 2017). In holobionts, such as ourselves, self-referential experiential consciousness is present within all of our own innate cells and all of our obligatory microbial partners. Together, they create a holobionic aggregate consciousness. Total consciousness, as we experience it, is a conjoining illusion. It is a matter of layered differential constituencies that are available at the present moment to interact, according to their faculties and limits. Thus in holobionts, consciousness as typically experienced, or its anesthetic limitations, is dependent on the vast variety of the cellular constituents that constitute cellular ecologies, each with its own metabolic and homeostatic set points. This is not nearly just a brain centered process. As a result, the physical basis of consciousness among all types of organisms can be clarified through the concepts of 'state consciousness' and 'system consciousness' (Gennaro, 1996; Kriegel, 2003, 2004; Berkovich-Ohana and Glicksohn, 2014). The former applies to individual cellular epimorphic states. The latter is constituted by the entirety of an organism and its networked cellular systems (Meijer and Geesink, 2017). How consciousness manifests among multicellular holobionts depends on the current status of aggregate consciousness of the collective participants compared to the normative state.

Within any macroorganic whole, each cellular participant is self-referential. Thus, observational measurement is being accomplished at some scales within that macroorganic entirety even when other collective informational elements (individual cells or collections of cells) are not functioning optimally or might even be inert. From this framework, the problem imposed by anesthetic states of consciousness is clarified. Consciousness at the level of the holobionic entirety as system consciousness is subdued in anesthesia. But other holobionic cellular participants, each with their own 'state consciousness' continue to observe and measure. This is obvious, since hearts beat and urine forms and peristalsis continues. Thus, consciousness, when judged through anesthetic states, is an expression of levels of active cellular networking. It is a matter of their individual state of function and their entangling connections. Therefore, any state of system consciousness is an observation of the functioning of a holarchy (a system defined by its elements in which each element is both a part and a whole). In a holobiont, as a complex superposition of scales of iterative state consciousness, some elements remain active while others are being suppressed. This is as true for crocodiles as it is for humans insofar as the structural and functional basis of phenomenal experientiality is a highly conserved evolutionary process (Behroozi et al., 2018). Therefore, human consciousness is a collective cellular process that has its own idiosyncratic manifestation of 'entire' consciousness based on the state consciousness of both its own distinct innate cells and its obligatory microbial partners. Together, they constitute a holobionic entire system consciousness of that is particular to each species and then, all individuals.

Certainly, it can be argued that there are scales by which different living organisms can be distinguished on the basis of subjectivity/subjectiveness (Reddy, 2017). In this regard, it is productive to conceive consciousness as a 'sense' (Tannenbaum, 2001). In that frame, consciousness is, "an emergent effect of an organizing process achieved through the sense of consciousness" (Tannenbaum, p.377). The value of this perspective increases when consciousness is understood as phenotype in which the senome is an integral part. Just as with any other phenotype, for example leg

muscles, its capacity to assist an organism in problem-solving is a product of usage. Sensory awareness should be similarly regarded, as an partially emergent and self-organizing in its own manner. Consciousness as a 'sense' phenotype would be a product of its senome and memory apparatus, both of which can be adjusted by either direct environmental or epigenetic impacts. The implication is quite direct. There is no reason to suppose that conscious phenotype is fixed, nor is there any reason to suppose that the informational management system of living organisms that underlies it is either. Everything in the living state is a flux dynamic. This all stands to reason. Any organism's attachment to information space-time is itself under continuous adjustment. Indeed, informational space-time for any organism is itself never fixed. A potentially discouraging implication therefore arises. It may be that any highly precise measurement of consciousness will always prove elusive. Any attempt to measure it, changes it, perhaps as a living analog to the Heisenberg Uncertainty Principle as a fundamental link to quantum mechanics.

From the foregoing, it can be defended that intelligence, cognitive complexity as abstraction, and creativity relate to the explicit level of combinatorial 'state conscious' awareness that is permitted by cellular networking as 'system consciousness'. Each of these forms of cognition is unique to every life form. Using this as a base, further intelligence becomes the ability to juggle more and more implicates prior to action. Abstract thought is the entertaining of implicates without any necessary action whatever. And creativity is the instability that is attained prior to the collapse of implicates into action or their simultaneous quenching due to a confusion of ambiguities. From the latter, it becomes a necessary counter-intuitive that creativity is as much a product of constraints as liberties.

With this as background, the cellular creativity that permits biological variety as phenotype can now be viewed as cellular engineering through measurement at the edge of chaotic inputs. Cellular problem-solving at that edge enables non-linear non-equilibrium responses to environmental stresses. The results are the mixed cellular ecologies that can become phenotypes. Most of these are matched to transient stresses and are culled by selection (Miller and Torday, 2018). Those few responses that are particularly balanced against enduring stress succeed. When self-referential solutions to environmental stresses are considered the essence of the living circumstance, then biology and its evolution must be regarded as inherently creative. Self-referential awareness is the simultaneous interrogation of informational aspects that are obvious and others that are obscured. The latter can be considered an informational analog of 'dark matter' that consists of dimensional manifold 'matching points' and interstices in information space-time from which creativity might arise as unanticipated outcomes. Selection is the default which defines the limits of that creativity. Therefore, biological creativity can be considered as an essential aspect of fundamental self-referential cognition. And as a necessary derivative, evolution, as cellular problem-solving, is no mere accident.

The prime lesson that can be gleaned from biological observation is that there is a substantial advantage to shared information space through mutualistic assessment. In this manner, the entirety of available information, conceptualized as its dimensional roundness, can yield to collective assessment. Creative novelty is one of its embedded yields, gained by navigation among the ambiguities of information space-time through those collective means. Thus, it is not surprising that similar to Bohm and Hiley (1975), Thiese and Krafatos (2016) indicate that throughout the universe, the properties of the whole cannot be predicted based on the specific characteristics of any of the individual participating entities that comprise that entirety. In every instance, the sum is

more than the collection of its parts. The living state and the nested ecologies that result are seamless wholes whose simultaneous operations depend on an innate biological complementarity, just as predicted by Bohr and Delbruck (Theise and Kafatos, 2013b.)

Certainly, all aspects of the cell including the senome, genome, epigenome, and memory-based molecular structural arrangements of the cell are part of memory-encoding. They all serve as functional aspects of information management that enable measurement (Jose, 2018). Therefore, it might be wondered as to how far down 'self' goes? This is obviously unknown. However, some structural parts of the cell appear to demonstrate many aspects 'self.' It is known that genetic elements can compete through meiotic drive by preferentially attaching to the spindle in a non-Mendelian distribution yielding biased transmission (Akeru et al., 2017). Research has demonstrated that 'selfish' chromosomes can cheat in the meiotic transmission of haploid gametes (Akeru et al., 2017; Núñez et al., 2018). Therefore, it can be argued that any 'competition' between genetic elements that yields discriminatory differences goes beyond chemical bonds and constitutes its own form of 'self.' Even further, the critical aspect of immunology as a locus of selfhood, explored by Tauber (2002), finds that immunity governs the inner self as highly context dependent communication directed towards homeostasis and protection against any aggressive outer 'other' self.

It is often forgotten, but very important that any single eukaryotic cell is consortium of several cells. Mitochondria and plastids, and perhaps also nuclei and peroxisomes, are descendents of ancient symbiotic events (Baluska et al., 2004a,b; Baluska et al., 2012; Baluska and Lyons, 2018a,b). Importantly, integration of these 'cells within cell' is based not only on the cellular cognition inherent to these organelles still retaining some aspects of their cellular 'self' identity, but also on synaptic cell-cell communication principles (Baluska and Mancuso, 2014). For example, it is possible that mitochondria, as assimilated prokaryotes within eukaryotic cells, have their own capacity of self that becomes an expression of extended conscious phenotype. Mitochondria exhibit individualistic reactions to cellular environmental stress within the cellular compartment (Ford, 2017). Furthermore, they also individually control distinct molecular cascades that govern cellular sensing and reactions to stress including viral infection (Galluzzi et al., 2012). Their role in programmed cell death is critical and their known adaptive responses have led to the belief that mitochondria sense and control cell-wide danger signaling (Galluzzi et al., 2012). All of these are related to self-identity. The endoplasmic reticulum, a tubular organelle, forms extensive connections with mitochondria to form mitochondria-ER associated membranes (MAMs) (Marchi et al., 2014). These membranes have distinct biochemical properties and unique sets of proteins that assist in the regulation of calcium transfer. Together, these organelles coordinate essential aspects of cellular metabolism and autophagy. Although it is not clear which aspects of the cell are absolutely essential to self-reference, such as microtubules, mitochondria, endoplasmic reticulum, genetic material or membranes, it can be asserted that any cell is an embodiment of its 'entire' self, even if there is some reducible aliquot. Therefore, for all practical purposes, it is the complete cell in its essential boundary conditions that exerts its effects.

Plainly, there is no current solution to the enigma of the origin of self-reference. However, it is clear that the living state is defined by universal sense-awareness and connectedness (Miller, 2017; Torday and Miller, 2018). It is directly argued that any purposeful future inquiry into evolutionary development must be based upon deliberations within two requisite parameters. First, all cells are self-referential. And second, all macroorganic entities are obligatory holobionts as highly inter-dependent collaborative and

competitive mixed cellular/microbial ecologies. Therefore, the evolutionary 'self' must be considered as a product of the totality of the participants in these mixed cellular ecologies that conjointly determine physiology and behavior. Simply put, our consciousness is collective cellular consciousness that is reiteratively enacted as an aggregate that comprises self-referential holobionic collective life. Thus, its augmentative emergent evolutionary expression emanates from its cellular baseline to which it retains permanent attachment. Indeed, this is obvious, as we are all an elaborated product of a single cell.

8. What can biology say to physics?

Einstein and Bohr had debated whether unexplained randomness underlies physics as hidden variables (Greenberger et al., 1989). Whether true or not, it can be asserted that the essential aspect of biological 'self' is its ability to deal with either case. Although the highly pertinent question of what is 'real' in physics continues apace, for the living organism at any scale, the issue can be clarified. *What is real for the living is doubt.*

Walker et al. (2016) have suggested that biology is a means of constraining unknown physics. Yet, that question can be rephrased. How might biology inform physics? Does biology subsume other properties beyond known physics that somehow relates to its systematization? In particular, what has this to do with biology seeming to be more than a simple integrated summation of its discrete particulars? Walker et al. (2016) offer a perspective: "Biology is distinguished as a physical system not by its causal structure, which is set by the laws of physics, but in how the flow of information directs the execution of function." (p.10).

If such is the case, then perhaps the best approach is through the categorization of information flows between cells as nodal state interactions through which levels interact in distinct ways over space and time. Such a Bayesian network can be modeled along the lines of a Markov blanket (Margaritis and Thrun, 2000). This is a network of nodes consisting of parents, its children, and any other parents of its children. The probability distribution of each node within the network is conditionally independent of the other nodes in the network. This structure provides linkages but individual integrity is maintained. In a living context, biological outputs can be seen as a dynamical emergent property of nodal participants that retain semi-autonomous function. It has been proposed that all living systems are nested systems of such Markov blankets, and further, that these have intrinsic self-organizing properties based on the resolution of uncertainties and the suppression of surprise (Kirchhoff et al., 2018).

Since cellular organisms are aggregates of individualized informational architectures, there must be a causal structure that enables interactions among those distributed nodes and permits mediation across levels. It has been proposed that this active global control of those individual information flows belongs to a 'control kernel' which connects informational architecture to the causal mechanisms of the network (Walker et al., 2016). Thus, a relevant frame can be proposed. When information has primacy, the collective life form is an information management system as a single functioning unit wherein the distributed informational architectures of the individual participants are only semi-dependent on the whole. Retaining local control can be directly rationalized. This is the level that maximizes the density and quality of information as measurable EI*. This optimized information can be directed towards maintaining the homeostatic equipoise of each of the individual constituents yet can still productively ramify under the aegis of a protective entirety.

Our actual biological circumstances mirror this. All multicellular eukaryotic life exists within a holobionic context of collective

participation by many differing semi-autonomous entities that conform to a nodal architecture. Furthermore, this combined living entity always yields to the unicellular zygotic form with its demonstrated adjudicating role over the expression of epigenetic inputs (Torday, and Miller, 2016d; Miller, 2016a, 2017; Miller and Torday, 2017, 2018). That passage can now be seen as a tool of information management and represents an explicit biological expression of a 'control kernel' concept. The 'control kernel' is the unicellular form whose recapitulation is obliged. This is the form in which information density and quality are maximized.

Given the foregoing, what can be conjectured that biology might teach physics? It is offered that any such instruction would have to be through the mystery of self-reference. Self-reference permits the emergent property of extracting information from physical data that yields collaborative life. Since energy and information are entwined stipulations in a self-referential plane, the enigmatic crux of the living state reduces to the means by which physical energy is purposed as useful information in context (Ho, 1998; Miller, 2016a, 2017). Both are necessities for the recognition of self and the protection of self-identity.

Grandpierre et al. (2014) had proposed that Bauer's principle could be regarded as the universal principle of biology. They quote Bauer as indicating that: "The living and only the living systems are never in equilibrium; they permanently invest work on the debit of their free energy budget against that equilibration which should occur for the given initial conditions of the system on the basis of the physical and chemical laws". From this, it is argued that the living state has fundamental differences and various indeterminacies compared to the inanimate. In particular, physical states conform to the least action principle whereas living states do not. It is offered herein that Bauer's principle might be productively modified to include a further entailing codicil. Bauer's principle is enabled by the measuring self-referential assessment of information space-time. Thus, a reconciliation between physics and the living state can be offered. Physical states conform to least action. In the living state, living organisms measure information and their individual and collective choices are guided by 'least uncertainties'. In terms of energy dissipation, this is entirely in keeping with a 'least action' principle. Purposeful action to maintain homeostatic equipoise based on EI^* is least action through the conservation of energy. Therefore, EI^* , as sets of 'least uncertainties', and 'least action' through the principle of conservation of energy, are equivalent stipulations.

It seems logical that the energy-information equation must always balance. Therefore, the question devolves into those exact means by which energy gains sufficient coherence to become information to any sender/receiver within the bounded, resonant cell (Rodríguez-Rosario et al., 2013; Miller, 2016a; Geesink and Meijer, 2017). In terms of the physics of biology, self-referential action within any cell is a form of non-equilibrium energy dissipation as a specialized form of energy transfer. Any 'new' physics that biology might instruct would then need to be specifically appraised as the manner in which energy is entrained as biological information (Miller, 2016a, 2017). Therefore, it is argued that a requirement for grasping biology centers on a thorough understanding of the self-referential information cycle which directly asserts the interconvertibility of triadic energy-information-communication (Miller, 2017; Miller and Torday, 2018). This is the manner in which energy is purposed through information towards obligatory biological communication. It is this specific recursive phenomenon, as can only be achieved within the self-referential frame, that enables the concerted mutualistic niche construction activities and natural cellular engineering that define prokaryotic biofilms and eukaryotic evolution (Odling-Smee et al., 2003; Laland et al., 2011; Miller, 2016a, 2017; Shapiro, 2017; Miller and Torday, 2018).

Therefore, it is argued that the proper exploration of the living circumstance lies within a greater understanding of how EI^* (non-random information that permits a cell to act in its own behalf) yields 'least action' through 'least uncertainties'.

It is further asserted that an ingrained bias must be overcome if there is to be any useful reconciliation between biology and physics. The informational architecture that underlies every living organism is not itself a product of natural selection. That architecture is the result of the instantiation of self-reference as a phase transition (Miller, 2016a). From that moment, selection subsumed its essential subordinate role. And it is exactly through that enigmatic transformation that any potential for a new physics for life should be sought. That explanation can only be found by finding the means by which information, as an inherently local property, somehow, "calls the shots" (Walker and Davies, 2016).

It should not be surprising that straightforward Newtonian rules are not a feature of biology as they are in the physical world. The cell and its sub-systems cannot be explained by conventional physical principles. Witzany and Baluška (2015) note, "because cell-to-cell communication depends on shared rules to use signs according to contextual needs, physical principles are not an appropriate tool for a better understanding of biological processes and sub-cellular organization." (p. e1009796-3). Within a context of ambiguous information, it may be unclear as to which explicit rules should be followed. Biology offers its solution. The collaborative multicellular processes that characterize eukaryotic life as a 'living' flow of information has its own dynamical rules as their terms of engagement. As Ulanowicz (2007) notes, the eminent physicist Walter Elsasser maintained that "all attempts to seek 'laws' akin to those used in physics to explain biological phenomena are patently illogical." (p. 948). However, that does not mean that there are not rules of the road. Clearly, there must be underlying consistent forces that dominate to reasonably understand observable results. It is defended that those rules can be identified. Instantiated self-referential cognition governs all cells in the maintenance of their preferred homeostatic states and permits the entire range of interchanges between cells. Therefore, the defense of that self-reference is the rule.

Thus, a conjecture can thus be offered. Just as physics had been initially defined through a classical Newtonian frame and new concepts of quantum mechanics were required to bring a fuller understanding of the physical world, the issue of self-referential consciousness as the fundament of biology will only be comprehended within its own analogous new frame. Clearly, self-reference as the living state is dependent on information. And further, biological information can only be understood as conditioned within ambiguity. Crucially, those uncertainties cannot solely be judged by any direct measuring of standard metrics of degradation by distance, time, or medium of transfer that yield noise in the conventional sense. Instead, there is the further requirement of an exploration into antipodal information that coexists in information space, in all its various forms, and consequently provides the crucial delta shift from direct information to its encompassing realm of implicates and doubt. Thus, biological information depends on 'adjacents' and 'empty' interstices and those obscured cues of predictions and anticipations which encompass the entire totality of senomic experience of self-referential living things including those eventualities that do not come to pass. Together, they shift 'round' information towards its 'matching', yet shifted antipodes. Indeed, in a cellular network as complex as any holobiont, any such shift might be sufficient enough that the same information might be viewed as a contrary superimposition of possibilities in an informational matrix at one cellular ecological level versus another. The ultimate biological expression may well be negotiated (Gilbert and Tauber, 2016). Therefore, it can be considered that the reality of

doubt that defines our living circumstance lies within that consequential self-referential shift.

Clearly, there is information that we 'know'. Certainly, too, there is information 'that we know that we do not know'. Beyond that, there is information that we do not know by direct observation, but can 'know' by inference. Further yet, there is information that we do not 'know' that we know. The collapse of superimposed implicates into explicate information is the settling of quantum probabilities from sets of quantum inferences as settled eigenstates. It is proposed that the eigenstates that result from antipodal-information represents the 'sub-conscious' as the settling of temporary self-referential quantum inferences. If the 'simplest' of organisms can judge and anticipate within its scale and thereby can act in its own interest, then the attachment to biological information space-time and its inherent ambiguities includes an attachment to antipodal information space-time at every scale as a form of deep inferential information. It can be argued that it is the latter that permits intuition, subliminal consciousness and creativity. Therefore, it should be no surprise that they are all interdependent phenomena.

Information space-time for any organism is a composite of direct and antipodal information assessed within a self-referential frame. Our responses to stress are through our 'rational' senses as perceived consciousness and by other cellular pathways that can be likened to 'physiology'. Both represent cellular summations within entire holobionts. One is overtly 'conscious'. The others might be termed our 'gut' feelings. Both are honored in our assessment in information space-time. Therefore, searching for self-referential consciousness exclusively within our brain is no longer realistic. Our consciousness must be modeled as a product of a sub-system–system–super-system akin to the Bohm's systematization of organisms (Bohm and Hiley, 1975; Tannenbaum, 2001). We and all other holobionts are a collection of mixed cellular/microbial ecologies united into a single functioning entity. This is an ecological dynamic (Ulanowicz, 2007). Any comprehension of our own essential self-reference, and any further consciousness, and then, our own form of idiosyncratic intelligence, must channel through the exact nature of the dynamic self-referential information flows between the varied constituencies of which we are comprised.

It is proposed that from this self-referential frame, one essential unification of biology with physics can be offered. In quantum physics, prior to observation, a quantum event is a superimposition of possibilities. The collapse of the wave function is due to a triggering observation. Thiese and Krafatos (2016) note that "... quantum phenomena are contextual, one cannot speak of 'independent' outcomes without the measurement context used to examine such phenomena." Further too, they quote John Archibald Wheeler, "no phenomenon can be presumed to be a real phenomenon until it is an observed phenomenon." Therefore, as physics is a science that is itself based on measurement, a credible understanding of biology as measurement resolves any inherent discontinuity between these scientific fields. *When self-reference is properly regarded as the fundamental essence of biology, then, biology and physics are directly reconciled. They are both differing modes of measurement.*

9. Conclusions

Cognition-Based Evolution proposes three essential distinctions from the conventional Darwinian evolutionary narrative: self-referential conscious awareness is the primary organizing principle of biology, the cellular form is its epitomic centrality, and biology and evolutionary development represent the defense of self-referential cognition at reiterating scales. Irrespective of its origin, once instantiated, self-referential cognition sustains the homeostatic equipoise of all cells. Since the self-referential attachment to information space-time has inherent ambiguities, the fundamental living

dynamic is self-organizing cellular collaboration and mutualistic competition directed towards the protection of individual cellular self-requisites as embodied self-identity. Multicellular mutualisms are the advantaged cellular solution towards that end. Its achievement directs through the maximization of EI* and the enactment of significant energy efficiencies through the self-referential trading of resources and divisions of labor. A straightforward defense of this alternative stance can be offered. Since the rise of Eukaryota some billions of years ago, cells intensely collaborate but rarely coalesce. Thus, the living circumstance can be fairly defined as the continuous process of the conservation of self-reference.

As a result, any multicellular form can now be appraised as the conjoining means by which the self-referential integrity of each of its constituents is best safe-guarded against agitating external stresses. The same principle justifies all multicellular eukaryotes as obligatory holobionts. The best means of attaining continuous environmental-organismal complementarity is through the mutualistic protections afforded by the shared appraisal of the ambiguities of information space-time. The holobionic form permits that assessment at reiterating scales, be that as individual constituents, at the level of each ecology, or ultimately, at the level of the entire organism. Therefore, holobionts are concordant solutions to imposed environmental stresses in which the individual states of preference of all the self-referential participants are achieved by collaborative means. To gain those protections, all holobionic ecologies are products of natural cellular engineering as mutualistic niche constructions. It is these consensual entanglements that grant long-term reproductive success.

Through the self-directed assessment of information at every scope and scale, self-referential measurement drives evolutionary development. Since cells can appraise and measure, they can engineer. To do so, they use their tools at their scale. As cellular beings at our scale, we measure and engineer using ours. In all instances, selection assures that the measurements are correct. In the self-referential frame, which is the imposed living circumstance, evolution is the continuous maintenance of homeostasis through the collective measurement, prediction and anticipation of information and its deliberate communication by intelligent ecological constituencies. Post-facto selection reinforces that mutualism.

In such a frame, cognition, in all its forms, represents an entanglement of cellular quantum coherences, resonances, criticalities and instabilities. All such biological actions are directed towards the settling of informational ambiguities as the cardinal condition imposed on all living things and which separates the animate from the inanimate. Therefore, the proposition of 'what is life?' can be reduced. *It is fundamental epitomic cellular self-referential cognition and the means through which it links in self-iterative patterns.*

The early 20th-century naturalist Henry Beston (1992 edition) eloquently described the idiosyncratic nature of earthly sensations and intelligence: "The animal shall not be measured by man. In a world older and more complete than ours, they move finished and complete, gifted with extensions of the senses we have lost or never attained, living by voices we shall never hear. They are not brethren, they are not underlings; they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendor and travail of the earth." So too, the illimitable self-referential cell.

Conflicts of interest

The authors declare no conflicts of interest.

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