INFORMATION IS NOT A THIRD FUNDAMENTAL QUANTITY OF THE UNIVERSE

Jaime F. Cárdenas-García, William B. Miller & František Baluška

ABSTRACT: The concept of information gained significant importance in the mid-twentieth century when Claude E. Shannon introduced the mathematical theory of communication. This groundbreaking development marked the birth of information science and the dawn of the 'Information Age'. The fascination with the concept of information spurred its application across various scientific disciplines, leading to the widely accepted yet flawed notion that information is a fundamental quantity of the universe, alongside matter and energy. Contrary to this view, more than twenty years after Shannon's proposal, Gregory Bateson defined information as the detection of *a difference which makes a difference* (to someone). This perspective emphasizes the role of information in the actions of living beings, as they assess changes in their environment to enhance their well-being. The concept of infoautopoiesis, or information self-production, describes a self-referential, recursive process of sensation-information-action intrinsic to living beings. This process underscores the importance of information for living organisms and illustrates how Shannon's information theory fits into this broader context. In summary, this paper challenges the validity of the widely accepted but flawed concept of information as a fundamental quantity of the universe.

KEYWORDS: Semantic information; Syntactic information; Claude E. Shannon; Gregory Bateson; Infoautopoiesis; Senome

INTRODUCTION

The Information Age emerged within the background of the mathematical theory of communication (Shannon, 1948) whose general elements are depicted in Figure 1 below. These seemingly uncomplicated elements have been crucial to the establishment of 'Information Theory' as a discipline. The objective of this depiction is to illustrate how a message, encoded as a digital signal, is sent from an Information Source (a microphone into which a message is spoken) that starts the communication process. The Transmitter is an encoding device that makes the Message generated by the microphone amenable to transmission as a Signal over a wired or wireless Channel. The Channel is subject to accumulation of

Noise from multiple Noise Sources. The Receiver is a decoding device that reconstructs the original message from the Received Signal. Finally, the Destination is the speaker that broadcasts the arriving Message. Shannon defines the fundamental problem of communication as "that of reproducing at one point either exactly or approximately a message selected at another point" (Shannon, 1948, p. 379).

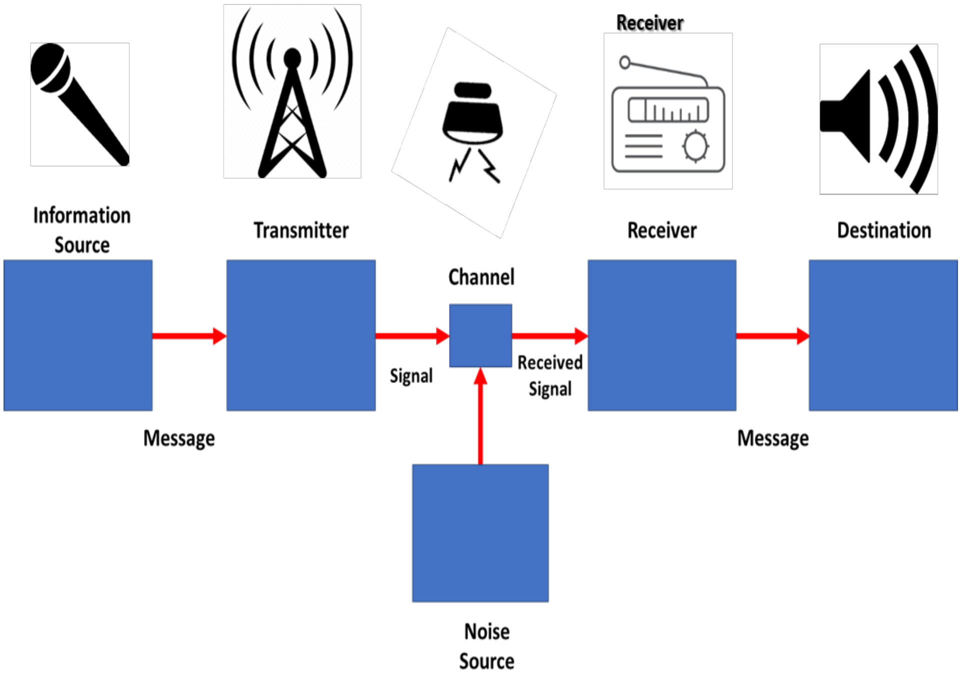

Figure 1 – The process of communication [adapted from (Shannon 1948)]

This engineering analysis was devised to understand and solve the problem of communication, emphasizing the syntactics of communication, i.e., the spoken word as syntactic information codified as binary digits, devoid of intrinsic meaning as semantic information. In devising this communication scheme Shannon came up with what is considered the first language model (LM), "… we understand the term language model (LM) to refer to systems which are trained on string prediction tasks: that is, predicting the likelihood of a token (character, word or string) given either its preceding context or (in bidirectional and masked LMs) its surrounding context. Such systems are unsupervised and when deployed, take a text as input, commonly outputting scores or (sic) string predictions" (Bender et al., 2021, p. 611). One highly pertinent aspect of

Shannon's theoretical proposal is that it assumes the transmission of a message, without specification of its origin. This assumption is critical for resolving engineering problems that seek to optimize the transmission of the digitally encoded message. However, this seemingly insignificant assumption stimulated the belief among many researchers that information is something that naturally exists in the environment. This presumption represented one aspect of information theory that Shannon (1956, p. 3) cautioned about when stating, " It will be all too easy for our somewhat artificial prosperity to collapse overnight when it is realized that the use of a few exciting words like *information*, *entropy*, *redundancy*, do not solve all our problems." Also, "Only by maintaining a thoroughly scientific attitude can we achieve real progress in communication theory and consolidate our present position."

THE ORIGIN OF INFORMATION

There is a surprising inability to define what information is, either because of its variety or because of the myriad criteria used to categorize it. The following quote by Bogdan (1994, p. 53) serves to put in perspective the confusion that exists with regard to the use of the concept of information by researchers, and the cautionary take by Shannon (1956) briefly touched upon above,

> My skepticism about a definitive analysis of information acknowledges the infamous versatility of information. The notion of information has been taken to characterize a measure of physical organization (or decrease in entropy), a pattern of communication between source and receiver, a form of control and feedback, the probability of a message being transmitted over a communication channel, the content of a cognitive state, the meaning of a linguistic form, or the reduction of an uncertainty. These concepts of information are defined in various theories such as physics, thermodynamics, communication theory, cybernetics, statistical information theory, psychology, inductive logic, and so on. There seems to be no unique idea of information upon which these various concepts converge and hence no proprietary theory of information.

This paragraph does little to clarify what information is and even implies that there seem to be many competing concepts of information that may be similarly valid. More saliently, there is an implied confusion as to whether information exists independently in the environment or somehow comes into being and has a traceable origin. Thoroughly examining how researchers view the origin of information should help lead to a better understanding of what information is and the role that it plays in nature.

Information as a postulate

Our examination of information begins by considering the work of Norbert Wiener, computer scientist, mathematician, philosopher and professor of mathematics at the Massachusetts Institute of Technology. Wiener is considered the originator of cybernetics, the science of communication applied to living things and machines, and known for his famous dictum: "Information is information, not matter or energy. No materialism which does not admit this can survive at the present day" (Wiener, 1961, p. 132). Not only is information defined in terms of itself, but information is considered an absolute quantity of the universe on an equal footing with matter and/or energy. Matter and energy are unequivocally fundamental quantities of the universe, while information hardly qualifies as such. This means that the belief that information is a fundamental quantity is grounded on a postulate. This view is a widely shared perspective among many leading scientists, which accounts for its ubiquity within many disciplines and deserves exploration.

The work of Daniel C. Dennett III, whose research centered on the philosophies of mind, science, and biology, with an interest in evolutionary biology and cognitive science also reflects this perspective about information as a fundamental quantity of the universe. We choose to examine a fragment on an essay on Intentional Systems whose behavior is said to "… be–at least sometimes–explained and predicted by relying on ascriptions to the system of beliefs and desires (and hopes, fears, intentions, hunches, …)" Dennett (1981, p. 3). This fragment is written in the context of travelling to a distant planet and finding it inhabited by things that seem unlike humans beings. In this context Dennett suggests making predictions as to the behavior of these alien beings and to do it on our own familiar terms. In these circumstances, Dennett (1981, p. 9) states,

> It might at first seem that this tactic unjustifiably imposes human categories and attributes (belief, desire, and so forth) on these alien entities. It is a sort of anthropomorphizing, to be sure, but it is conceptually innocent anthropomorphizing. We do not have to suppose these creatures share with us any peculiarly human inclinations, attitudes, hopes, foibles, pleasures, or outlooks; their actions may not include running, jumping, hiding, eating, sleeping, listening, or copulating. All we transport from our world to theirs are the categories of

> rationality, perception (information input by some "sense" modality or modalities—perhaps radar or cosmic radiation), and action. The question of whether we can expect them to share any of our beliefs or desires is tricky, but there are a few points that can be made at this time; in virtue of their rationality they can be supposed to share our belief in logical truths, and we cannot suppose that they normally desire their own destruction, for instance.

Notice that perception is viewed as "information input" implying that the creatures being examined have the capacity for sensing information from their environment. We can assume that that is also the belief that carries over from our earthly existence.

Another biology educator and philosopher, Tom Stonier, is an information theorist who shares a similar perspective as Dennett and explicitly states (Stonier, 1990, p. 114),

> In the light of the above considerations, if the first axiom of a general theory of information is:
>
> **Information is a basic property of the universe**,
>
> the second axiom must be:
>
> **The information contained by a system is a function of the linkages binding simpler, into more complex units.**
>
> A derivative conclusion of this second axiom is:
>
> **The universe is organised into a hierarchy of information levels.**

Stonier (1997, p. 14), emphasizing the syntactic aspects of information, further states "The information theory proposed earlier by the present author (Stonier, 1990), assumes information to be a basic property of the universe – as fundamental as matter and energy. Specifically, a system may be said to contain information if such a system exhibits organization."

In short, Stonier takes an approach based on postulates to describe information from a fundamental perspective, including allusions to its syntactic nature. "(I)f such a system exhibits organization", whose organization does it exhibit?

John Archibald Wheeler was a notable theoretical physicist largely responsible for reviving interest in general relativity in the United States after World War II. He worked with Nobel Prize winner Niels Bohr to explain the basic principles of nuclear fission, and popularize the term "black hole" for objects with gravitational collapse. A most notable assessment of information by Wheeler (1990, p. 5) is,

> In default of a tentative idea or working hypothesis, these questions, no's and clues — yet to be discussed — do not move us ahead. Nor will any abundance of clues assist a detective who is unwilling to theorize how the crime was committed! A wrong theory? The policy of the engine inventor, John Kris, reassures us, "Start her up and see why she don't go!" In this spirit I, like other searchers attempt formulation after formulation of the central issues, and here present a wider overview, taking for working hypothesis the most effective one that has survived this winnowing: It from bit. Otherwise put, every it — every particle, every field of force, even the spacetime continuum itself — derives its function, its meaning, its very existence entirely — even if in some contexts indirectly — from the apparatus elicited answers to yes or no questions, binary choices, bits.
>
> It from bit symbolizes the idea that every item of the physical world has at bottom — at a very deep bottom, in most instances — an immaterial source and explanation; that what we call reality arises in the last analysis from the posing of yes-no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and this is a participatory universe.

The origin of the Universe, for Wheeler (1990), summarized as 'It from bit' implies that there is no need to assume anything else for everything around us to be realized. Immateriality becomes materiality by fortuitous postulate.

David Chalmers is a professor of philosophy and neural science at New York University (NYU), as well as co-director of NYU's Center for Mind, Brain and Consciousness (along with Ned Block). He specializes in philosophy of mind and philosophy of language, and is best known for formulating the hard problem of consciousness, and for popularizing the philosophical zombie thought experiment. In explaining the application of cognitive models to consciousness David Chalmers (1996, p. 31) states,

> Cognitive models are well suited to explaining psychological aspects of consciousness. There is no vast metaphysical problem in the idea that a physical system should be able to introspect its internal states, or that it should be able to deal rationally with information from its environment, or that it should be able to focus its attention first in one place and then in the next. It is clear enough that an appropriate functional account should be able to explain these abilities, even if discovering the correct account takes decades or centuries. But the really difficult problem is that of phenomenal consciousness, and this is left untouched by the explanations of psychological consciousness that have been put forward so far.

The notion of information as originating in the environment is a major assumption by Chalmers, further arguing that consciousness can be productively parsed into distinct categorical forms of conscious apprehension of those environmental cues. Significantly, this conclusion is based on philosophical perspectives at the level of human consciousness, divorced from exploring how cells process information, which necessarily represents the basic substrate of our sensory systems.

The research of Terrence William Deacon, Professor of Anthropology and member of the Cognitive Science Faculty at the University of California, Berkeley, combines human evolutionary biology and neuroscience in an effort to gain insight into the evolution of human cognition. His studies include the study of semiotic processes underlying animal and human communication, especially language and language origins. A more nuanced perspective is found when Deacon (1997, p. 30) states,

> Evolution is diversification in all directions, but there are more options available in some directions than others. Organisms started out small and short-lived and couldn't get much smaller, but they could always get larger and more long-lived. For the smallest organisms, the resources that can be devoted to internal representations of the world are limited, though even bacteria appear able to use their one information-storage system, their genes, to take in information from around them and modify their behaviors appropriately. But the upper end of the range of information-handling abilities was not similarly bounded, and so the difference between the low end and the upper end of this range has increased over the hundreds of million years of animal evolution as part of this diversification. Nevertheless, the number of small-brained creatures has not diminished because of competition with those with big brains, and the no-brainers-all the plants and single-celled organisms-vastly outnumber the rest of us. It just happens that one very, very minor evolutionary direction is toward niches where doing a lot of information processing during one's life is a good way to pass on genes. Inevitable? Well, it's about as inevitable a direction in evolution as the development of arctic fish with antifreeze in their blood or electric eels who use electricity to sense their way through muddy Amazonian waters. The niche was just there, and was eventually filled. Still, in some measure, we are near the extreme of this distribution.

How organisms 'take in information from around them' is not explained, but assumes that information exists in the environment for organisms to assimilate and use.

Eva Jablonka is professor at the Cohn Institute for the History of Philosophy of Science and Ideas at Tel Aviv University. Jablonka is an evolutionary theorist and geneticist, known especially for her interest in epigenetic inheritance, as a leading proponent of the extended evolutionary synthesis.

Jablonka (2002, pp. 581–582) in attempting to define biological information states,

> On the basis of the common properties just listed, all of which are necessary for something to be referred to as "information," I shall suggest a semantic definition of information. I shall argue that when thinking about biologically relevant information, a functional-evolutionary perspective is necessary, but the focus should be neither on the evolution of the signal "carrying" the information, nor on the evolution of the final specific response. Rather, it should be on the evolution of the system mediating between the two—on the interpreting system of the receiver. The definition I suggest accommodates environmental cues as potential informational sources, and makes it easier to think about non-genetic information and its transmission through non-genetic inheritance systems.

This approach to information emphasizes accommodating "environmental cues as potential informational sources".

Stephen Wolfram is computer scientist, physicist, and businessman, known for his work in computer algebra and theoretical physics. As a businessman, he is the founder and CEO of the software company Wolfram Research, where he works as chief designer of Mathematica and the Wolfram Alpha answer engine. In the context of a discussion about 'What is Computation? (How) Does Nature Compute?' (Calude et al., 2011, pp. 388–389) Stephen Wolfram states the following,

> This question about whether abstract formal systems are about something or not is a question that obviously has come up from mathematics. And my guess about the answer to this question: is information the primary thing or is matter the primary thing? I think that the answer to that question would probably end up being that they are really the same kind of thing. That there's no difference between them. That matter is merely our way of representing to ourselves things that are in fact some pattern of information, but we can also say that matter is the primary thing and information is just our representation of that. It makes little difference, I don't think there's a big distinction – if one's right that there's an ultimate model for the representation of universe in terms of computation.

This view strongly mirrors Wheeler's framework that computational exchanges form the basic universal substrate, though stated differently.

Christof Koch, a student of late Nobel Laureate Francis Crick and

Meritorious Investigator at the Allen Institute for Brain Science, has had a significant role in promoting Integrated Information Theory in pursuing consciousness research (Tononi et al., 2016). In explaining how humans engage sensorially with the environment Koch (2004, p. 237) states,

> Given the many senses—eyes, ears, nose, tongue, skin—that flood the brain with information about the environment, and given the diverse effectors controlled by the brain—eyes, head, arms and fingers, legs and feet, the trunk—breeding zombie agents for all possible input-output combinations is probably inefficient. Too many would be required as well as something that coordinates their actions, in particular when they pursue conflicting aims. Such a nervous system would, in all likelihood, be bigger and less flexible than a brain that follows a hybrid strategy of combining zombie agents with a more flexible, conscious module.

Here again, the implicit assumption of intrinsic environmental information rears its head.

Another notable educator is Hubert P. Yockey. A physicist and information theorist who worked under Robert Oppenheimer on the Manhattan Project, and at the University of California, Berkeley. Yockey (2005, p. 6) examined how information theory applies to evolution and the origin of life stating, "Information, transcription, translation, code, redundancy, synonymous, messenger, editing, and proofreading are all appropriate terms in biology. They take their meaning from information theory (Shannon, 1948) and are not synonyms, metaphors, or analogies." By relying on Shannon, Yockey is wedded conceptually to syntactic information and the notion of pre-existing information in the environment.

Seth Lloyd is a quantum information scientist and professor in the Massachusetts Institute of Technology Department of Mechanical Engineering. He has done foundational work in quantum information science, including work on designs for a quantum computer, quantum analog computation, quantum analogs of Shannon's theorem, and novel methods for quantum error correction and noise reduction. The topic of a quantum informational universe is also a theme reflected by Lloyd (2006, p. 10) as represented in the following statement,

> This book is the story of the universe and the bit. The universe is the biggest thing there is and the bit is the smallest possible chunk of information. The universe is made of bits. Every molecule, atom, and elementary particle registers bits of information. Every interaction between those pieces of the universe processes that information by altering those bits. That is, the universe computes, and because the

> universe is governed by the laws of quantum mechanics, it computes in an intrinsically quantum-mechanical fashion; its bits are quantum bits. The history of the universe is, in effect, a huge and ongoing quantum computation. The universe is a quantum computer.

Once again there is an explicit assumption of information as a pre-existing quantity of the universe as a computational function substrate. Accordingly, life is a quantum computational derivative.

Stuart Anspach Umpleby is a cybernetician and professor in the Department of Management and Director of the Research Program in Social and Organizational Learning in the School of Business at the George Washington University. The following overview by Umpleby (2007, p. 369) provides a historical perspective about how different civilizations viewed the universe and approached the concept of information,

> The ancient Greeks believed that the constituents of the universe were earth, air, fire and water. (Aristotle, 1952). The Chinese believed that the basic elements were metal, wood, water, fire and earth (Gao, 1985). Currently physicists emphasize space and time. General systems theorists often speak of matter, energy and information as fundamental categories. For example Miller's (1978) living systems theory is based on the idea that cells, organs, organisms, groups, corporations, nations and supranational organizations all process matter, energy and information. In biological systems (e.g. cells, organs and organisms) matter and energy are so closely related that they are often treated as one entity—matter/energy. A social organization such as a corporation processes matter (e.g. by transforming raw materials into finished products), energy (including the fuel and electricity needed to operate machines and heat buildings) and information (e.g. customer orders, advertising messages and accounting records).

In each of these perspectives, the environment has pre-existing information that must be organized, forming the essential elements. How information is created is not directly addressed.

Professor Mark Burgin, a renowned mathematician, logician, computer scientist, and information theoretician, is widely recognized for his groundbreaking contributions to a broad range of fields, including mathematics, information sciences, algorithm theory, and epistemology. Burgin (2010) had compiled a comprehensive history and conceptualization of information resulting in a unique general theory of information (GTI) (Burgin & Cárdenas-García, 2020; Krzanowski, 2023). The GTI is described by two groups of principles. The first or *ontological principles* explain the essence of information as a natural and artificial phenomenon as well as depict regularities of information functioning. The second or *axiological principles*, explain how to measure information, which measures of information are necessary, and how to build them. Since the ontological principles categorize "the essence of information as a natural and artificial phenomenon" the implication is that information has an originating connection to nature and the environment, but is implicit to the living frame.

Vlatko Vedral is a physicist best known for his contributions to quantum information theory, quantum mechanics, and quantum entanglement. Vedral (2010, p. 10) suggests that,

> As pointed out by Deutsch and Wheeler, however, whatever candidate is proposed for the fundamental building block of the Universe, it still needs to explain its 'own' ultimate origin too. In other words, the question of everything from nothing, creation ex nihilo, is key. So if, as I claim, information is this common thread, the question of creation ex nihilo reduces to explaining how some information arises out of no information. Not only will I show how this is possible, I will also argue that information, in contrast to matter and energy, is the only concept that we currently have that can explain its own origin.

Thus Vedral (2010) not only brings us back to a perspective where information is fundamental but also makes the argument that information is the essence of itself. Again, we assert that these arguments are based on unprovable postulates.

Luciano Floridi is a philosopher best known for his work on the philosophy of information (PI) and information ethics. Currently he is director of the Digital Ethics Center at Yale University and Professor of Sociology of Culture and Communication at the University of Bologna. Floridi (2011, p. 30) more circumspectly states in discussing the philosophy of information (PI),

> Let us start by taking the bull by the horns:
>
> PI THE ELEMENTARY PROBLEM: WHAT IS INFORMATION?
>
> This is the hardest and most central problem in PI and this book could be read as a long answer to it. Information is still an elusive concept. This is a scandal not by itself, but because so much basic theoretical work relies on a clear analysis and explanation of information and of its cognate concepts.
>
> Information can be viewed from three perspectives: information as reality (e.g. as patterns of physical signals, which are neither true nor false), also known as environmental information; information about reality (semantic information, alethically qualifiable); and information for reality (instructions, like genetic

information, algorithms, orders, or recipes).

This triadic viewpoint, wedded to the environment as the source of information, neatly encapsulates the choices that must be made to have a coherent information theory and compactly defines the issues that must be explained to justify cells as informational agents, or as 'inforgs' (informational organisms), as proposed by Floridi (2014).

Howard Hunt Pattee is a biologist and Professor Emeritus at Binghamton University and Fellow of the American Association for the Advancement of Science. His research work in theoretical biology has a focus on origin of life, artificial life, biosemiotics, semiotic control of dynamic systems, and the physics of codes and symbols. The following quote by Pattee (2013, p. 11) presents information as a 'fundamental primitive concept',

> Before I knew of the field of biosemiotics, the relatively few linguists and semioticians that I encountered were resistant to extending the concept of language to the genetic level. Also, much of the foundational literature of biosemiotics has been critical of the concept of information. For example, Hoffmeyer (2008, p. 61) says, "For an up-to-date biology must acknowledge that the biochemical concept of information is just too impoverished to be of any explanatory use." He concludes (p. 68), "I believe that in the end this futile metaphor [of information] will only serve to pull the wool over the eyes of ourselves and others." On the contrary, as a physicist I believe information is a fundamental primitive concept, and all semiotic concepts are forms of information.

Gordana Dodig-Crnković is a Professor of Computer Science at Mälardalen University and a Professor of Interaction Design at Chalmers University of Technology, Sweden, with PhD degrees in Physics and Computer Science. Prof. Dodig-Crnković's research focuses on the relationships between computation, information, and cognition, including ethical and value aspects. Dodig-Crnkovic, relying on Floridi, seems to regard information as a fundamental reality yet still emphasizes its observational terms and the necessity of its epistemic value (Dodig-Crnkovic, 2013, p. 116) by stating that,

> The universe is, from the metaphysical point of view, "nothing but processes in structural patterns all the way down" [12, p228]. Understanding patterns as information, one may infer that information is a fundamental ontological category. The ontology is scale-relative. What we know about the universe is what we get from sciences, as "special sciences track real patterns" [12, p242]. This idea of an informational universe coincides with Floridi's Informational Structural Realism

[13,14]. We know as much of the world as we explore and cognitively process:

> *"Reality in itself is not a source but a resource for knowledge. Structural objects (clusters of data as relational entities) work epistemologically like constraining affordances: they allow or invite certain constructs (they are affordances for the information system that elaborates them) and resist or impede some others (they are constraints for the same system), depending on the interaction with, and the nature of, the information system that processes them."* [13, p370].

César A. Hidalgo is a physicist and professor of social and behavioral sciences at the Toulouse School of Economics and director of the Center for Collective Learning. Hidalgo is known for his work on economic complexity, relatedness, data visualization, applied artificial intelligence, and digital democracy. In addressing the topic of information Hidalgo (2015, p. 9) states,

> The universe is made of energy, matter, and information, but information is what makes the universe interesting. Without information, the universe would be an amorphous soup. It would lack the shapes, structures, aperiodic orders, and fractal arrangements that give the universe both its beauty and its complexity.

In so doing, Hidalgo is asserting observational agency to matter and energy to create fundamental agency, thereby asserting fundamental environmental information as an elemental universal postulate.

Artemy Kolchinsky and David Hilton Wolpert have influenced the way that semantic information may be approached from a Shannonian perspective (Kolchinsky & Wolpert, 2018). Artemy Kolchinsky holds a position as a Marie Curie fellow at the Pompeu Fabra University, Spain; and works at the intersection of nonequilibrium thermodynamics, information theory, and complexity science. Being broadly interested in understanding the relationship between information and energy in physical and biological systems. David Hilton Wolpert is a physicist and computer scientist who holds an appointment as professor at the Santa Fe Institute. In an influential paper, Kolchinsky and Wolpert (2018, p. 2) state,

> In order to maintain themselves, autonomous agents must typically observe (i.e. acquire information about) their environment, and then respond in different and 'appropriate' ways. For instance, a chemotactic bacterium senses the direction of chemical gradients in its particular environment and then moves in the direction of those gradients, thereby locating food and maintaining its own existence.

Thus, Kolchinsky and Wolpert subscribe to a notion of information dependent on a postulate which leads to questioning the basis for their notion of semantic information.

Carlo Rovelli is a theoretical physicist and Emeritus Professor at the Centre de Physique Theorique of Marseille in France and a Distinguished Visiting Research Chair at the Perimeter Institute. In writing about information Rovelli (2018, p. 21) states,

> My aim is now to distinguish the correlations that are ubiquitous in nature from those that we count as relevant information. To this end, the key point is that surviving mechanisms survive by using correlations. This is how relevance is added to correlations.
>
> The life of an organism progresses in a continuous exchange with the external environment. The mechanisms that lead to survival and reproduction are adapted by evolution to a certain environment. But in general environment is constantly varying, in a manner often poorly predictable. It is obviously advantageous to be appropriately correlated with the external environment, because survival probability is maximised by adopting different behaviour in different environmental conditions.
>
> A bacterium that swims to the left when nutrients are on the left and swims to the right when nutrients are on the right prospers; a bacterium that swims at random has less chances. Therefore many bacteria we see around us are of the first kind, not of the second kind. This simple observation leads to the Kolchinsky-Wolpert model [5].

Rovelli relies on Kolchinsky and Wolpert (2018) to make his case for the existence of environmental information.

The following account by Fresco et al. (2020, p. 548) is also clear as to finding information in the environment that acts as 'functional information' for a living being, stressing its ambiguities,

> Various taxonomies of information already exist in the literature (e.g., Floridi 2011; Maynard Smith and Harper 2003; Millikan 2004; Queiroz et al. 2011; Scarantino and Piccinini 2010) with little agreement on how and when to use them. One may therefore wonder how the proposed taxonomy improves on the current situation. The short answer is that we build on a well-received taxonomy in animal communication theory (cue/signal) to clarify different types of so-called "non-natural" information that apply beyond nonhuman animal communication. It is often assumed that non-natural information and representation are extensionally equivalent. However, by understanding information from a functional perspective, we claim that there are instances of functional information that may qualify as "non-natural information", yet, calling them 'representations' lacks explanatory justification. Organisms exploit information about the environment (distal as well as proximal), and they may do so without necessarily representing the environmental feature(s) concerned.

Michael Levin a developmental and synthetic biologist at Tufts University, where he is the Vannevar Bush Distinguished Professor, director of the Allen Discovery Center at Tufts University, and co-director of the Institute for Computationally Designed Organisms with Josh Bongard and Chris Fields. Their body of work emphasizes the existence of information in the environment (Fields & Levin, 2020, pp. 3–4),

> While definitions of "life" and "living system" are numerous, varied, and controversial [58–62], all agree that every living system exists in interaction with an environment. If Life on Earth as a whole is considered a living system [35,37,63,64], its environment is by definition abiotic; for all other living systems (on Earth), the environment has both abiotic and living components. Definitions of life agree, moreover, that at any given instant *t*, the state $|S\rangle$ of a living system S is distinct, and distinguishable, from the state $|S\rangle$ of its environment E (we borrow Dirac's $|\cdot\rangle$ notation for states from quantum theory: $|X\rangle$ is the state of some system X). This condition of state distinguishability, called "separability" in physics, guarantees that the interaction between a living system and its environment can be viewed, without loss of generality, as an exchange of classical information [65–67].

Pam Lyon is an Associate Faculty at the University of Adelaide that works in the biology and evolution of cognition. Pam Lyon (2015, p. 3), in discussing cognition in organisms, mentions the existence of information in the environment,

> Discussions of cognition across phyla often degenerate into qualms about definition that typically begin with 'yes, but what do you mean by...' The concept that guides this investigation will be specified therefore. Because we are not concerned with the special capacities of a single mammalian species (i.e., Homo sapiens), a general definition from comparative psychology will serve, with some modification. Shettleworth (1998, p. 5) defines cognition as "the mechanisms by which animals acquire, process, store, and act on information from the environment. These include perception, learning, memory, and decision making." Cognition thus is comprised of the total suite of mechanisms that underwrite information acquisition, storage, processing, and use. Although this definition can be applied to phyla Shettleworth (1998) may not have had in mind, e.g., microbes, it is (for the most part) uncontroversial within the domain of comparative psychology and cognitive ethology.

Yann André LeCun, Silver Professor of the Courant Institute of Mathematical Sciences at New York University and Vice President, Chief AI Scientist at Meta, is a computer scientist working primarily in the fields of machine learning, computer vision, mobile robotics and computational neuroscience. In 2018, LeCun, Yoshua Bengio, and Geoffrey Hinton, the "Godfathers of AI", received the Turing Award for their work on deep learning. Yann LeCun's extensive research toward achieving autonomous machine intelligence (Dawid & LeCun, 2023; LeCun, 2022) seeks to enable the use of world models. In this context, to differentiate his work from that of machine learning models, LeCun (2022, p. 2) states,

> Animals and humans exhibit learning abilities and understandings of the world that are far beyond the capabilities of current AI and machine learning (ML) systems.
>
> How is it possible for an adolescent to learn to drive a car in about 20 hours of practice and for children to learn language with what amounts to a small exposure. How is it that most humans will know how to act in many situation they have never encountered? By contrast, to be reliable, current ML systems need to be trained with very large numbers of trials so that even the rarest combination of situations will be encountered frequently during training. Still, our best ML systems are still very far from matching human reliability in real-world tasks such as driving, even after being fed with enormous amounts of supervisory data from human experts, after going through millions of reinforcement learning trials in virtual environments, and after engineers have hardwired hundreds of behaviors into them.
>
> The answer may lie in the ability of humans and many animals to learn world models, internal models of how the world works.

What seems evident from these statements and more extensive interpretation of his work is that he seems to believe that information exists in the environment and can be easily captured and extrapolated as he suggests 'Animals and humans' are able to do.

Lee Cronin is the Regius Professor of Chemistry at the University of Glasgow. His research focuses on creating artificial life forms, finding alien life, exploring the digitization of chemistry, understanding how information can be encoded into chemicals and constructing chemical computers. Professor Sara I. Walker is an astrobiologist and theoretical physicist at Arizona State University. Her research interests are in theoretical advances in the field of astrobiology, developing new approaches to the problem of understanding universal features of life that might allow a general theory for solving the problem of the transition to life from matter and energy, to, detecting alien life and designing synthetic life. Both Cronin and Walker have been instrumental in the development of Assembly

Theory (AT) to explain and quantify biological selection and evolution (Marshall et al., 2017; Sharma et al., 2023; Walker et al., 2020).

In discussing assembly theory they assign information to environmental components (Sharma et al., 2023, p. 324),

> To produce an assembly space, an observed object is broken down recursively to generate a set of elementary building units. These units can be used to then recursively construct the assembly pathways of the original object(s) to build what we call assembly observed, A_O. A_O captures all histories for the construction of the observed object(s) from elementary building blocks, consistent with what physical operations are possible. Because objects in AT are compositional, they contain information about the larger space of possible objects from which they were selected. To see how, we first build an assembly space from the same building blocks in A_O, which include all possible pathways for assembling any object composed of the same set elementary building blocks as our target object. The space so constructed is the assembly universe (A_U).

Marko Vitas, an Independent Researcher doing research in Molecular Biology and Biochemistry, is interested in the emergence of life. He asserts the existence of information in the environment in arguing for consciousness (Vitas, 2025, p. 3),

> In my view, information in biology should be conceptualized in its broadest sense in terms of interactions with environments, e.g. chemotaxis, where the gradient of glucose is detected by bacteria. To survive in the harsh, competitive world, an organism must continually acquire information about the state of the outside environment, store this information, process it, and use it to compute favourable responses (Tlusty and Libchaber, 2025). There is certainly a flow of information from environments to living system (Kolchinsky and Wolpert, 2018).

Lastly, in a recent paper in the American Physical Society journal PRX Life, Bartlett et al. (2025, p. 1) state,

> One important way that organisms achieve intrinsic goals is by changing their behavior in response to different environments [13,14]. In this way, organisms acquire, process, and use information about environmental states for functional purposes. This kind of information usage has been variously termed functional [15,16], meaningful [17], and semantic [14] information in the literature (with subtle differences).

Clearly, the topic of information as fundamentally residing in the environment is ubiquitous to the work of many researchers.

This limited survey of the literature reveals that the conceptualization of information is still a topic of intense debate. Many prominent researchers argue that the environment is the source of information and consider it a fundamental quantity of the universe, alongside matter and energy. This suggests that much of the theorization in information science may be based on a flawed premise, implying that existing theories need further scrutiny. Consequently, there is a pressing need for an alternative approach to underpin future developments in information science, particularly its connections with other disciplines such as physics, biology, computer science, mathematics, engineering, and the arts.

Information as a Derived Quantity/Quality

Given this metaphorical Gordian knot of conceptualizing information based on a postulate it seems that a resolution has to be sought by firsthand observation, looking for an alternative approach seeking to define information as a derived quantity.

Figure 2 shows a modified process of communication, including the human actors that originate the sounds that are the basis for oral communication labelled as syntactic information. When Shannon ignored the meaning of the message he was in effect ignoring the source of the syntactic information, i.e., the human speaker on the left side of Figure 2. It is clear that the individual on the left has the intent of communicating with the individual on the right side of the figure. This implies that if we are to develop a complete theory applicable to the science of information, we have to include both semantic and syntactic information, and have a precise understanding of how both are produced. In this important quest, we need to be curious about how humans develop the ability to have something to say to one another.

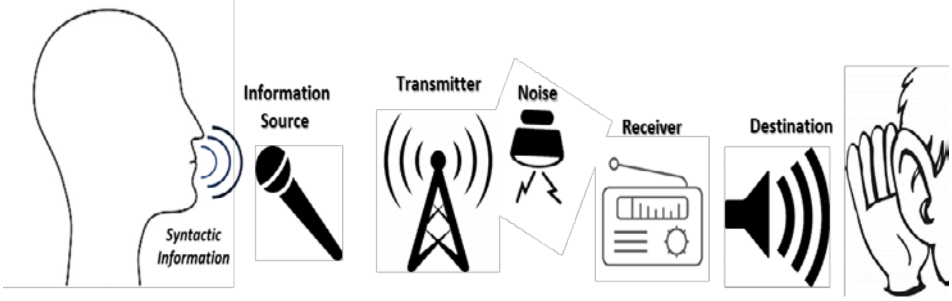

Figure 2 – The modified process of communication

Further, we need to be able to define information and how it applies to the process of human communication. More generally, we need to clarify "… how a human organism, in a self-referential process, is able to develop from a state in which its knowledge of the human-organism-in-its-environment is almost non-existent to a state in which the human organism not only recognizes the existence of the environment but also sees itself as part of the human organism-in-its-environment – and which allows the human organism to not only self-referentially engage with the environment and navigate through it, but to even transform it in its own image and likeness. In other words, 'the fundamental problem of the science of information' concerns the phylogenetic development of humankind, as well as the ontogenetic development of human individuals, in an ever changing long-term and short-term environment. This process of human organism development is a process in which information is its underlying primary motor" (Cárdenas-García & Ireland, 2019, p. 231).

What is this concept of information that serves as the motor of human development? To gain some insight into the process of the generation of semantic and syntactic information, let us reexamine information from two other perspectives. The first examines its etymological origin. The word information has the Latin stem *informatio*, from the verb *informare* (to inform) in the sense of giving a form to matter and communicating knowledge to others (Capurro, 2009; Capurro & Hjørland, 2003; Díaz Nafría, 2010; Peters, 1988). For an organism-in-its-environment this implies a dynamic outlook. Therefore, there is a before and an after when the organism engages with matter/energy. For example, the Sender of the message in Figure 2 uses his sound organs to manipulate air to create air pressure waves to form the needed message so as to be intelligible on reception. A second analogous and dynamic perspective is that of Bateson's "difference which makes a difference" (Bateson, 1978, p. 453). Bateson's conceptualization is applicable when observing nature around us, as well as when acting on nature to determine the effects of our actions. Both conceptions of information define a self-referential, interactive, recursive, evolving, and never-ending virtuous dynamic spiral of sensation-information-action. The actions reflect the organismic capacity for relating to their environment motivated by satisfaction of physiological and/or relational needs (Cárdenas-García, 2020, 2022a, 2022b, 2023). This perspective leads to the consideration that "The essence of this definition is that information is something which is generated by a subject. Information is always information for "someone"; it is not something that is just hanging around "out there" in the world" (Hoffmeyer, 1996, p. 66). Implying "that there is no information outside living beings interacting with their environments" (Gare, 2020, p. 328). Thus, Bateson complements the etymology of the word information by its parallel dynamic interpretation. For example, when giving shape to an object it is clear that what is required is a reinforcing cycle of sensing-information-action from the initial shape and consistency of matter to its final shape as a useful object. This triadic virtuous cycle of sensing-information-action requires further elaboration to discover its semantic and syntactic information underlayers, as described below.

INFOAUTOPOIESIS

We begin by considering what may be regarded as the fundamental unit of life, an infoautopoietic (info = information; auto = self, poietic = creative/productive) organism as depicted in Figure 3 below. This depiction relies on the Fundamental Problem of the Science of Information (Cárdenas-García & Ireland, 2019, p. 213) as mentioned above. The recursive and interactive behavior of this infoautopoietic organism is what drives its development as a function of how it perceives the environment to promote its own development motivated by satisfaction of its physiological and/or relational needs; as well as how the changes that it produces in the environment shape its continuous development. It is an organism trapped in an ever-expanding environment that accommodates its ever-developing actions and possibilities. This is the story that we seek to explore. In clear opposition to information postulated as a fundamental environmental element, we explore how information originates and grows as a result of infoautopoiesis (info = information; auto = self, poiesis = creation/production).

The goal is to explain how the Fundamental Problem of Information is realized, i.e., how living beings become what they become. In Figure 3 we identify internal and external circuits that define the sensation-information-action triad. The **internal** or **infoautopoiesis circuit** begins at the point

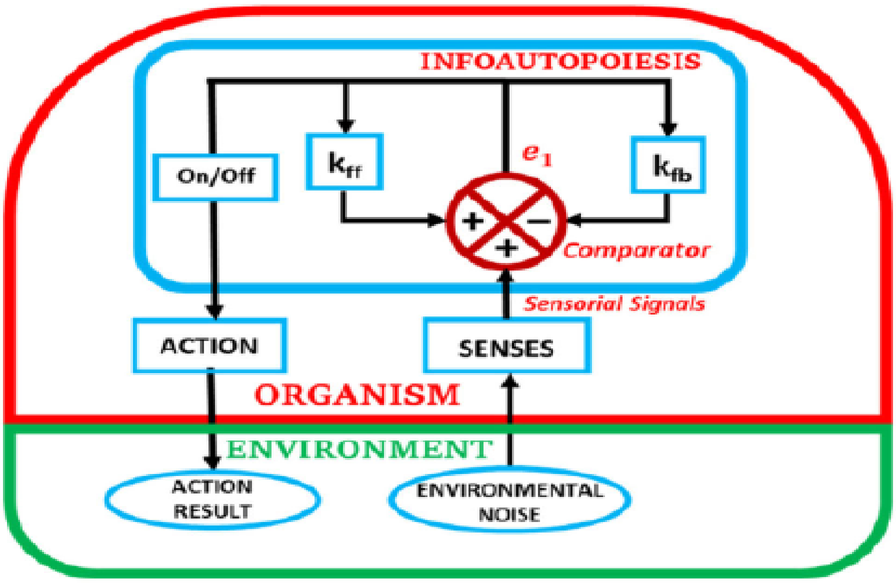

Figure 3 – The infoautopoietic organism (Cárdenas-García, 2024)

where the infoautopoietic organism Senses select Sensorial Signals to self-create/produce information; and ends where the infoautopoietic organism exerts an Action and acts on the environment. The **external circuit** connects the environment to the infoautopoietic organism: the Senses are at the input side of the organism where Sensorial Signals are selected from Environmental Noise, and the action-capable members produce an Action that results in an Action Result on the output side of the organism. These two circuits define the self-referential, recursive, and interactive process of self-production of information from Sensorial Signals.

A crucial element of this sequence is that all these actions occur at the level of individual cells, which represent the fundamental unit within biology (Baluška et al., 2023; Baluška et al., 2022; Miller et al., 2020; Miller, 2023). An understanding of cellular circumstances clarifies the process of infoautopoiesis as an obligatory aspect of cellular life .

Semantic (internal) information creation is motivated by the individuated satisfaction of physiological and/or relational needs leading to a meaningful external environment. An Action results in Shannon/syntactic (external) information (a metaphor for the creation of all our artificial artifacts, including all our Arts and Sciences) as an Action Result that seeks to cause recursivity in the actions of the organism. Notably, the syntactic information created as an Action Result, requires infoautopoietic translation by the organism, creating meaning-laden semantic information to continue to pursue the sensation-information-action virtuous cycle in pursuit of understanding the environment (Miller et al., 2025).

Crucially then, all Shannon/syntactic information is inaccessible except through semantic self-referential analysis, which leads to a living understanding of its transmitted Shannon/syntactic information expressions such as language, gestures, pictographs, music, sculptures, writing, coding, etc. Previous work explains in greater detail many of the details regarding the flow of information in Figure 3 (Burgin & Cárdenas-García, 2020; Cárdenas-García, 2020, 2022a, 2023, 2024). In short, infoautopoiesis provides an explanation of how meaning-making occurs and points to the origin of all human knowledge.

To recapitulate, our objective is to contrast infoautopoiesis (information self-production) with postulated intrinsic information in the environment. Indeed, how do the Senses of the infoautopoietic organism interact with the Environmental Noise identified in Figure 3 to yield Sensorial Signals that are amenable to information self-production? A key issue in this regard is whether the Environmental Noise inherently represents information or merely comprises matter-energy interactions that necessitates infoautopoietic analysis to constitute actionable information.

To better understand this issue, we must begin with a description of the typical arsenal of sensory elements that living organisms possess.

Our body is conservatively composed of millions, if not billions, of sensory elements distributed across the five senses: touch, sight, hearing, taste and smell. Each sensory element may be considered an infoautopoietic gateway. The coordination of all these infoautopoietic elements results in a very complex sensation-information-action cycle. This process defies modeling since the transformation from Sensory Signals to semantic information is unknowable; the transformation from semantic to Shannon/syntactic information is also unknowable; and the coordination between sensory elements that may differ in function and location is also unknowable. In short, infoautopoiesis is undecipherable, which carries the necessary entailment that the Binding Problem is unsolvable (Herzog, 2009).

When we identify Environmental Noise as existing in the environment, the elephant in the room is the word 'noise'. What is noise? Noise may be construed subjectively as any sound that is unwanted. But when a living being is first brought into this world and is faced with an unknown environment which includes noise in its many forms, can we argue that that indeterminate environmental noise is unwanted? Noise can come from many sources: sound, light, touch (mechanoreceptors, thermoreceptors, nocireceptors, proprioceptors), smell and taste. These last two are associated with chemical sensation which might be more typical of bacteria chemotaxis (Keegstra et al., 2022). All of which share dimensions of magnitude, frequency, and time (duration and variation). Well-known examples include white noise (or "broadband noise" which contains all frequencies found in the spectrum of sounds you can hear in equal parts); and white light (a combination of all the frequencies, wavelengths, or colors of the visible light spectrum). Both define situations where it is difficult to discern any specific sound or color of light. Thus, when we speak about environmental noise it has to, in general, be different from white noise of any kind, since in most situations white noise would be a rare occurrence. But how do living beings learn to separate the wheat from the chaff, so to speak, in learning to discern Sensorial Signals, pertinent to the well-being of the infoautopoietic organism, from environmental noise?

One important though infrequently asked question is: what motivates an organism (however liminal) to detect 'a difference which makes a difference', i.e., to generate information or make a distinction? In general, researchers assume that the organism knows what it is doing and goes about its business of living. What we want to state unequivocally is that infoautopoietic organisms are motivated by the satisfaction of physiological and/or relational needs. And this applies since the origin of life, when a first distinction made by the first living being led to information and life. What specific need motivated that first living being is unknown and unknowable, but that it occurred is irrefutable. Having said that, what this implies and requires is that the infoautopoietic organism be primed to recognize what it needs, i.e., to identify the Sensorial Signals relevant to its welfare. This means that the organism knows what it is looking for, either consciously or unconsciously. Necessarily, then, all cells have instilled preferences and states of 'satisfaction' that must be addressed as an essential aspect of their living condition (Miller, 2013).

This type of phenomenon is typical of pareidolia. Pareidolia is a normal, adaptive and common tendency to perceive a specific, often meaningful image (or visual illusion) in a random or ambiguous (noisy) visual pattern. Implied in this characterization is that when pareidolia occurs, it is not something that is sought by an individual, rather it occurs spontaneously or reflexively. Such perceptions may also be expected when listening to random noise or music. Notice that pareidolia is related to a noisy visual image or random noise. This notion might be extended to other sensory realms as well. Face pareidolia is found to be prioritized by the visual system, as illustrated by Carl Sagan (1997, p. 46) in the following passage,

> Humans, like other primates, are a gregarious lot. We enjoy one another's company. We're mammals and parental care of the young is essential for the continuance of the hereditary lines. The parent smiles at the child, the child smiles back, and a bond is forged or strengthened. As soon as the infant can see, it recognizes faces, and we now know that this skill is hardwired in our brains. Those infants who a million years ago were unable to recognize a face smiled back less, were less likely to win the hearts of their parents and less likely to prosper. These days, nearly every infant is quick to identify a human face and to respond with a goony grin.

Another way to understand this predisposition on the part of a living being to anticipate what it needs is by considering Peircean semiosis (Peirce, 1931–36, 1958). Semiosis involves the production, exchange, and interpretation of signs as the basis for meaning to an organism. This process requires establishing a continuous and developing set of triadic relations between a representamen (sign), an object (the other), and an interpretant as the organism engages with its umwelt, resulting in the appearance of meaning as a factor in its life. While Peircean semiosis is said to be the most fundamental process to instantiate meaning-making in nature, it can be shown that an infoautopoietic approach is more fundamental is assessing meaning-making (Cárdenas-García, 2024).

It is in this context that Kalevi Kull (1998, p. 302), in defining semiosis, states,

> Thus, I define semiosis as a process of translation, which makes a copy of a text, suitable to replace the original text in some situations, but which is also so different from the original text that the original cannot be used (either spatially, or

> temporally, or due to the differences in text-carrier or language) for the same functions. This translation process (i.e., semiosis) requires two types of recognition processes. First, the translation assumes that parts of the original text are recognized (on the basis of pre-existing memory-text) and as a result new structures are built, whereas a certain isomorphism between the original and the new text is retained. And second, there is a recognition process which starts the translation process, which is required for the existence of the whole process on another level, and which at the same time gives an intentional dimension to any particular semiosis. I also state that the one carrying out the translation (the translator, which includes memory) is itself a text, i.e., the result of some translation process.
>
> From this definition it follows that semiosis always requires a previous semiosis which produced the translator. Since the translator already recognizes, i.e., matches with something, the form of which has been stored, i.e., which has previously been matched, it follows that the current translation process is preceded by some previous translation process. Also, the text used for translation is the product of a previous semiosis.

A pictorial representation of the process of translation described by Kull is shown in figure 4(a). The pre-existing text is depicted as [M_1, S_1] to represent a text both as a memory and a sign, respectively. In interacting with the 'Original Text' [O_1] an interpretant and sign [I_1, S_2] come into being, which in generating a 'Translated Text' [O_2] result in a new interpretant and sign [I_2, S_3], respectively.

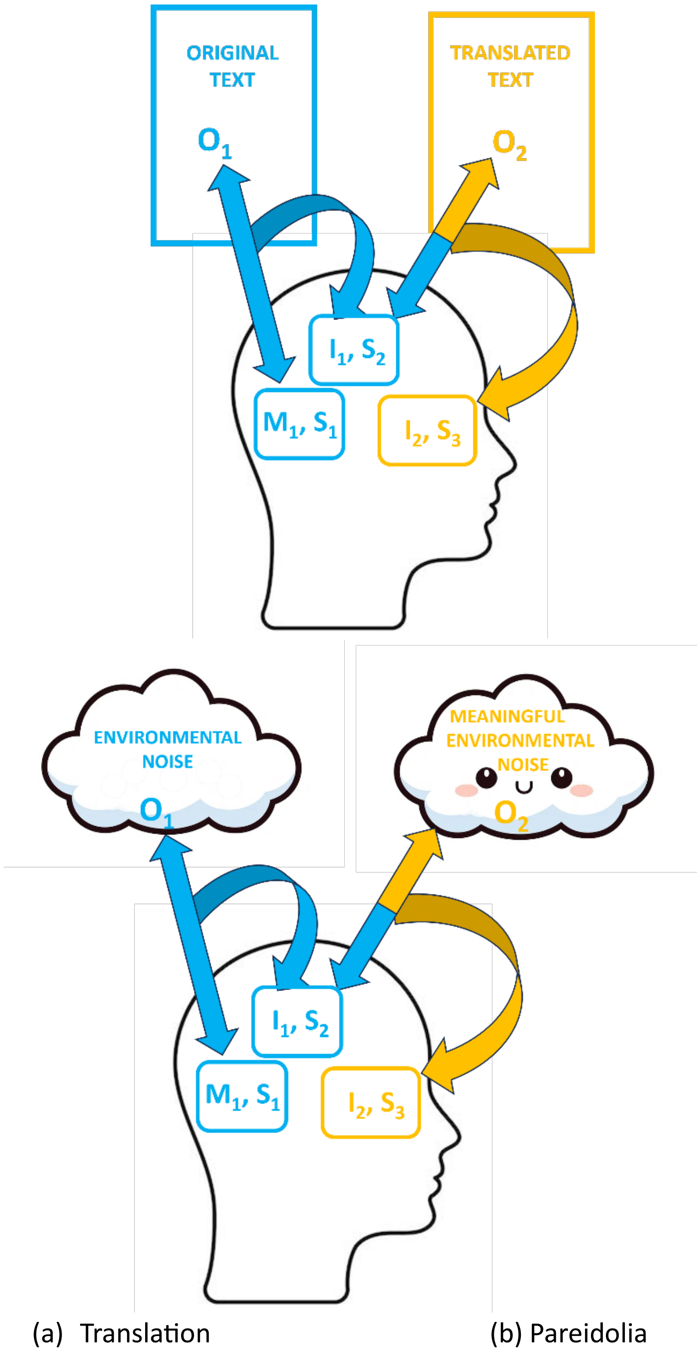

Figure 4 – Peircean semiosis

What this achieves is not only the capability to recognize existing texts, but also to create variant texts that may differ from the original text and may even contain newly elaborated elements in creative combinations. We posit that this process of translation identified by Kull (1998) might explain abduction as a third form of inference in addition to deduction and induction (Douven, 2025).

By assessing pareidolia as a translation process within a semiosis perspective, we arrive at the pictorial portrayal in Figure 4(b), which parallels that of Figure 4(a). In the case of pareidolia the original text is perceived as a random or ambiguous visual pattern (environmental noise) that ultimately results in what may be an illusory or true contextual representation of an object. Pareidolia is applicable to all aspects of the noisy environment in which an organism dwells. This also suggests that the organism does this initially without express awareness as to what it is doing: It does it instinctively or reflexively. This recursive and interactive occurrence leads to syntactic actions by the organism-in-its-environment that promote habituation. Any stimulus received by an organism through its sensory apparatus will begin the process of assessment to determine whether it should be permitted across its discriminating plasma membrane. Pareidolia is a means of assessment via immediate comparison to its memory-based, exclusive, self-referential representational map of external reality.

The concept of an individuated cell information field also helps to explain the process. Every cell has its own exclusive information field, which can be considered the purview of the possible environmental noise that a cell is capable of sensing in its efforts to satisfy its physiological and/or relational needs, including its embedded bioelectrical fields that extend outward beyond the cell's plasma membrane (Miller, 2016, 2018, 2023; Reber et al., 2023). This can be considered the cell's field of view, and when a stimulus first arrives from within that field of view, the organism will utilize a shortcut in the path to semantic self-generation of information through pareidolia-based patterns within its recognition systems. These same shortcuts pertain to multicellular organisms that share the information gleaned from their individual information fields into an organism-wide, collective sensorially based information field that guides a multicellular organism's response to environmental noise.

For complex infoautopoietic organisms this initial, triggered assessment becomes a conscious, recursive spiral of sensation-information-action. Pareidolia takes place at the boundary between Environmental Noise and the Sense elements in conjunction with the memory of the organism.

Another approach that sheds light on how sensory signals are recognized relates to the identification of the Senome, which represents the total sensory apparatus of a cell integrated with cellular metabolism, including its exclusive self-referential information field, that seamlessly links the cellular reception of environmental noise, their internal analysis, leading to self-created semantic information, which triggers its active deployment. Importantly, the senome acts very fast at milliseconds/seconds time scales, while the epigenome needs minutes to hours to modify the genome and gene expression. Each sensory experience perceived by an organism can be considered a unit of sensory experience (a *sene*) (Baluška et al., 2024; Baluška & Miller, 2018). In this regard, Baluška and Miller (2018, p. 5) state,

> The Senome translates physical signals from the outside world into the physico-chemical language of cells … The Senome functions as a plasma membrane-based cell-wide sensory organ of assessment and action that permits continuous coordinated organismal-environmental complementarity. When placed in the context of cellular cognition, the Senome is that aspect of the cellular life that interrogates the environment and guides cellular responses and adaptation as a problem-solving phenomenon.

The discriminating cell membrane and its linked memory are crucial aspects of the senome, along with a replete cellular apparatus for the assessment and translation of environmental stimuli linking to the cell's tools for the deployment of scant resources or triggering communication to other cells or viruses (Baluška & Miller, 2018). This senomic capacity crucially changes the framework of environmental exploration and the 'sensing' of the environment, since the senome is part of the heritable endowment of cells, transferred through cell division along with its genome.

Pareidolia can be assumed to represent a significant aspect of the initial senomic sensing of the external environmental and its initial membranous assessment as a gateway phenomenon. In effect, some things are recognizable from the 'get-go' since they are an aspect of inheritance (from membranes) that otherwise might get routinely ignored, initiated at the level of the cell's self-referential information field.

All living beings come equipped with inherited memories of appropriate responses to a range of environmental stimuli that directly relate to certain physiological and/or relational needs, which require satisfaction upon which life depends, such as a wildebeest calf standing almost immediately after birth to suckle and move. The senomic architecture continuously adds to this repertoire over time and additionally has the resources to flexibly and robustly respond to new stimuli. In this manner, the senome focuses the senses to select salient sensorial signals from the ambiguities of a noisy environment.

Summarizing, we have identified three different ways of how environmental noise is pre-processed by the infoautopoietic organism to arrive at Sensorial Signals that lead to infoautopoiesis as the self-creation of semantic information by the organism. In this manner, environmental information is a derived aspect of the living frame and not a fundamental environmental quantity as an unproven postulate.

DISCUSSION

A prevalent belief in information science—one with significant influence across numerous disciplines—is that information is a fundamental quantity in the universe in addition to matter and/or energy. This unsubstantiated postulate is widespread throughout scholarly literature, and its ready acceptance by many may impede progress by discouraging the active search for alternative theoretical perspectives that could yield fresh insights across various domains. An inhibiting factor is that information is variably defined, making it difficult to apply with rigor across disciplines.

Infoautopoiesis, as a fact-based, explanatory approach to information creation, challenges common assumptions. Information is not inherent to the universe but is a quantity/quality self-created by living beings. This perspective enables a unified concept of information applicable across scientific disciplines and clarifies how information and human knowledge evolve. If there is information in the environment, it is syntactic—created by living beings to shape nature into an artificial frame resembling ourselves. No similar approach exists in the current literature.

Infoautopoiesis may be defined in terms of the following principles of life,

- Life originated from an environment composed of matter/energy whose signature is (physio-chemical) noise as matter-energy fluctuations that have no contextual meaning, representing the background abiotic environmental state. Implicitly matter/energy interactions are required for the development of life given the right conditions;

- An infoautopoietic organism is the fundamental unit of life;
- Infoautopoiesis (information self-creation) is the basis for recursive interactions between the organism and its environment;
- Infoautopoiesis is the ability/preference of an organism to self-referentially generate information as 'a difference which makes a difference' from the detection of matter-energy interactions/fluctuations, motivated by the satisfaction of physiological/relational needs to support a state of homeorhetic preference;
- The detection of matter-energy interactions/fluctuations by an organism is subject only to their amplitude (high enough to detect, and low enough so as to not be negatively impacted) and its frequency (within the range of the sensory capabilities of the organism);
- Infoautopoiesis delimits the threshold for life;
- There are different kinds of infoautopoietic organisms, but no minimum infoautopoietic organism to at least the level of cells and potentially viruses;
- The process of infoautopoiesis consists of several stages in the ontogenetic recursive interactions between the organism and the environment that generate a senomic sensation-information-action ascending spiral cycle;
- Syntactic information creation imposes limits on the actions of an organism: an organism is incapable of creating artifacts able to generate semantic information. Thus, semantic information can lead to syntactic information but the translation of syntactic information to semantic, meaning-laden information requires another infoautopoietic organism;
- Infoautopoiesis, enabling the self-referential construction of semantic information, is the basis for all human knowledge/culture;
- Infoautopoiesis shows the improbability of finding a solution to the Neural Binding Problem.

Figure 3 shows how a human being is able to interact with its environment by externalizing internal semantic information through external expressions using language, gestures, pictographs, musical instruments, sculptures, writing, coding, etc., which is syntactic in nature and corresponds to Shannon information. In short, Shannon/syntactic information is a metaphor for all human creations. This includes all our artificial creations in the arts and sciences and all human artifacts which surround us.

To gain a measure of what we mean when we refer to syntactic information elements in our environment, we quote Pattee when he states, "For my argument here, I will mean by matter and energy those aspects of our experience that are normally associated with physical laws" (Pattee, 2012, p. 213). In other words, when we observe our environment and apply science and the scientific method to make sense of what we observe, we build an understanding that is based on our syntactic conceptualizations. We observe, experiment, and theorize using our syntactic creations, including mathematics, physics, and chemistry, to gain access to the world that surrounds us so that we can change it in our own image to serve our needs.

What this means is that all of what we discover and build is subject to interpretation by someone, so we have to teach every new generation how to understand and interpret our scientific creations. This chain of knowledge may sometimes be broken. Such was the case when we were unable to decipher Egyptian hieroglyphic script. The finding of the Rosetta Stone, the first Ancient Egyptian bilingual text recovered in modern times, allowed us to gain access to the inscribed knowledge. The explanations and practical achievements of science need to be constantly reevaluated since they all are the result of syntactic creation. In short, syntactic creation is only able to explain other syntactic elements in our environment.

In this regard, life is an element in nature capable of semantic interpretation for its own benefit as well as capable of syntactic creation to share its internal life. This is what permits life to complete the sensation-information-action cycle to close the circle of its metabolic connection with nature. This explains why our ability for syntactic creation limits our capacity to explain life, since life falls outside the realm of our syntactics-based scientific understanding. This implies that all efforts to use chemistry to attempt to create life are doomed to failure (Criado-Reyes et al., 2021; Miller, 1953).

To gain some insight on the impact of our syntactic creations, a new study finds that the mass of all our stuff—buildings, roads, cars, and everything else we manufacture—now exceeds the weight of all living things on the planet. And the amount of new material added every week equals the total weight of Earth's nearly 8 billion people (Elhacham et al., 2020). Pappas (2020) expressed it more explicitly in this manner,

> Roads, houses, shopping malls, fishing vessels, printer paper, coffee mugs, smartphones, and all the other infrastructure of daily life now weigh in at approximately 1.1 trillion metric tons—equal to the combined dry weight of all plants, animals, fungi, bacteria, archaea, and protists on the planet. The creation of this human-made mass has rapidly accelerated over the past 120 years: Artificial objects have gone from just 3 percent of the world's biomass in 1900 to on par with it today. And the amount of new stuff being produced every week is equivalent to the average body weight of all 7.7 billion people.

This is how information grows for human beings. These statistics offer an insight into the source of living creativity. Our innate living ability to self-create semantic information enables our production of syntactic inventions to successfully attain and maintain our states of preference and satisfactions.

CONCLUSIONS

Previously we mentioned that Bogdan does not see the possibility of the convergence toward a unique idea of information (Bogdan, 1994, p. 53). Specifically Bogdan mentions that

> The notion of information has been taken to characterize (1) a measure of physical organization (or decrease in entropy), (2) a pattern of communication between source and receiver, (3) a form of control and feedback, (4) the probability of a message being transmitted over a communication channel, (5) the content of a cognitive state, (6) the meaning of a linguistic form, or (7) the reduction of an uncertainty.

Reference numbers have been added to the text to differentiate between characterizations of information. Numbers 1, 2, 4 and 7 are linked to Shannon's mathematical theory of communication; while numbers 3, 5 and 6 are more attuned to Bateson's "difference which makes a difference." But both can be considered to be linked by infoautopoiesis and communication as represented in Figure 2, which comprises both syntactic and semantic information and clarifies their origin. The self-generation of internalized semantic information by an organism-in-its-environment results in externalized syntactic information that is communicated through a syntactical creation that allows communication to occur between individuals, near or far. This characterization of seven types of information are really the various forms in which information appears and is labeled in the communication process. Most significantly, all originate through infoautopoiesis.

The process of communication has existed since cognitive and sentient cellular life begun at least 3.8 billion years ago (Baluška et al., 2023; Baluška et al., 2022; Miller, 2013; Miller & Torday, 2018; Reber & Baluška, 2021). But it is not until Shannon defined the problem of communication, due to the digitization needs of the information age, that a measure of the physical organization of the message, the identification of a source and receiver, the nature and analysis of syntactic information, and increasing the probability of receiving the same message as it was sent, needed to be examined in developing "Information Theory." In a similar way, Bateson concerned himself with a more general theory of information that sought to characterize information as something fundamentally tied to our actions and interactions within our environment. Infoautopoiesis completes the circuit by considering how both conceptions of information can be used to explain how living beings become what they become by means of a senomically-based sensation-information-action cycle.

Information is not a fundamental quantity of the universe like matter and/or energy. Information is a derived quantity/quality through the self-referential infoautopoietic assessment of the motion of matter and/or energy by all living beings in pursuit of satisfaction of physiological and/or relational needs since the origin of life on earth.

ACKNOWLEDGMENT

The authors would like to acknowledge the reviewers and editor for their helpful, critical and insightful comments and suggestions, which have helped to significantly improve the content of this paper.

DEDICATION

JFCG dedicates this work to the memory of JCCN who inspired me to think about novel fundamental universals.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Jaime F. Cárdenas-García: Writing – review & editing, Writing – original draft, Conceptualization. **William B. Miller**: Writing – review & editing, Conceptualization. **František Baluška**: Writing – review & editing, Conceptualization.

Jaime F. Cárdenas-García*
Centro de Estudios Superiores Universitarios
Universidad Mayor de San Simón
Cochabamba, Bolivia
ORCID: 0000-0003-2405-4954
jfcardenasgarcia@gmail.com
* Corresponding author

William B. Miller, Jr.
Banner Heath Systems
6526 N. 59th St.
Paradise Valley, AZ 85253
wbmiller1@cox.net

František Baluška
Institute of Cellular and Molecular Botany
University of Bonn, Germany.
baluska@uni-bonn.de

REFERENCES

Baluška, F., Miller Jr, W. B., & Reber, A. S. (2024). Sentient cells as basic units of tissues, organs and organismal physiology. *The Journal of physiology*, *602*(11), 2491–2501. https://doi.org/https://doi.org/10.1113/JP284419

Baluška, F., & Miller, J. W. B. (2018). Senomic view of the cell: Senome versus Genome. *Communicative & Integrative Biology*, *11*(3), 1–9. https://doi.org/10.1080/19420889.2018.1489184

Baluška, F., Miller, W. B., Jr., & Reber, A. S. (2023). Cellular and evolutionary perspectives on organismal cognition: from unicellular to multicellular organisms. *Biological Journal of the Linnean Society*, *139*(4), 503–513. https://doi.org/10.1093/biolinnean/blac005

Baluška, F., Reber, A. S., & Miller, W. B., Jr. (2022). Cellular sentience as the primary source of biological order and evolution. *Biosystems*, *218*, 104694.

https://doi.org/10.1016/j.biosystems.2022.104694

Bartlett, S., Eckford, A. W., Egbert, M., Lingam, M., Kolchinsky, A., Frank, A., & Ghoshal, G. (2025). Physics of Life: Exploring Information as a Distinctive Feature of Living Systems. *PRX Life*, *3*(3), 037003. https://doi.org/10.1103/rsx4-8x5f

Bateson, G. (1978). *Steps to an ecology of mind; collected essays in anthropology, psychiatry, evolution, and epistemology*. Ballantine Books.

Bender, E. M., Gebru, T., McMillan-Major, A., & Shmitchell, S. (2021). *On the Dangers of Stochastic Parrots: Can Language Models Be Too Big?* Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency, Virtual Event, Canada. https://doi.org/10.1145/3442188.3445922

Bogdan, R. J. (1994). *Grounds for Cognition: How Goal-guided Behavior Shapes the Mind (1st ed.)*. Psychology Press. https://doi.org/https://doi.org/10.4324/9781315806426

Burgin, M. (2010). *Theory of Information - Fundamentality, Diversity and Unification*. World Scientific Publishing Co. Pte. Ltd.

Burgin, M., & Cárdenas-García, J. F. (2020). A Dialogue Concerning the Essence and Role of Information in the World System. *Information*, *11*(9), 406. https://doi.org/https://doi.org/10.3390/info11090406

Calude, C. S., Chaitin, G. J., Fredkin, E., Leggett, A. J., Ruyter, R. d., Toffoli, T., & Wolfram, S. (2011). What is Computation? (How) Does Nature Compute? In H. Zenil (Ed.), *Randomness Through Computation: Some Answers, More Questions*. World Scientific Publishing Co., Inc.

Capurro, R. (2009). Past, present, and future of the concept of information. *tripleC*, *7*(2), 125–141.

Capurro, R., & Hjørland, B. (2003). The concept of information. *Annual Review of Information Science and Technology*, *37*(1), 343–411. https://doi.org/https://doi.org/10.1002/aris.1440370109

Cárdenas-García, J. F. (2020). The Process of Info-Autopoiesis – the Source of all Information. *Biosemiotics*, *13*(2), 199–221. https://doi.org/10.1007/s12304-020-09384-x

Cárdenas-García, J. F. (2022a). The Central Dogma of Information. *Information*, *13*(8), 365. https://doi.org/https://doi.org/10.3390/info13080365

Cárdenas-García, J. F. (2022b). Info-Autopoiesis and Digitalisation. *New Explorations: Studies in Culture and Communication*, *2*(3). https://doi.org/https://jps.library.utoronto.ca/index.php/nexj/article/view/39029

Cárdenas-García, J. F. (2023). Info-Autopoiesis and the Limits of Artificial General

Intelligence. *Computers*, *12*(5), 102. https://doi.org/https://doi.org/10.3390/computers12050102

Cárdenas-García, J. F. (2024). Information is Primary and Central to Meaning-Making. *Sign Systems Studies - Special Issue on Contemporary applications of umwelt theory*, *52*(3/4), 371–393.

Cárdenas-García, J. F., & Ireland, T. (2019). The Fundamental Problem of the Science of Information. *Biosemiotics*, *12*(2), 213–244. https://doi.org/10.1007/s12304-019-09350-2

Chalmers, D. J. (1996). *The Conscious Mind: In Search of a Fundamental Theory* (Vol. 4). Oxford University Press.

Criado-Reyes, J., Bizzarri, B. M., García-Ruiz, J. M., Saladino, R., & Di Mauro, E. (2021). The role of borosilicate glass in Miller–Urey experiment. *Scientific reports*, *11*(1), 21009. https://doi.org/10.1038/s41598-021-00235-4

Dawid, A., & LeCun, Y. (2023). Introduction to Latent Variable Energy-Based Models: A Path Towards Autonomous Machine Intelligence.

Deacon, T. W. (1997). *The symbolic species: the co-evolution of language and the brain*. W. W. Norton & Company, Inc.: New York, NY.

Dennett, D. C. (1981). *Brainstorms: Philosophical Essays on Mind and Psychology*. The MIT Press. https://doi.org/10.7551/mitpress/1664.001.0001

Díaz Nafría, J. M. (2010). What is information? A multidimensional concern. *tripleC*, *8*(1), 77–108. https://doi.org/10.31269/triplec.v8i1.76

Dodig-Crnkovic, G. (2013). Alan Turing's Legacy: Info-computational Philosophy of Nature. In G. Dodig-Crnkovic & R. Giovagnoli (Eds.), *Computing Nature: Turing Centenary Perspective* (pp. 115–123). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-37225-4_6

Douven, I. (2025). *Abduction* (E. N. Zalta & U. Nodelman, Eds.). Metaphysics Research Lab, Stanford University. https://doi.org/https://plato.stanford.edu/archives/sum2025/entries/abduction/

Elhacham, E., Ben-Uri, L., Grozovski, J., Bar-On, Y. M., & Milo, R. (2020). Global human-made mass exceeds all living biomass. *Nature*, *588*(7838), 442–444. https://doi.org/10.1038/s41586-020-3010-5

Fields, C., & Levin, M. (2020). How Do Living Systems Create Meaning? *Philosophies*, *5*(4), 36.

Floridi, L. (2011). *The philosophy of information*. Oxford University Press.

Floridi, L. (2014). *The fourth revolution: How the infosphere is reshaping human reality*. Oxford University Press.

Fresco, N., Ginsburg, S., & Jablonka, E. (2020). Functional Information: a Graded Taxonomy of Difference Makers. *Review of Philosophy and Psychology*, *11*(3), 547–567. https://doi.org/10.1007/s13164-018-0410-7

Gare, A. (2020). Semiosis and Information: Meeting the Challenge of Information Science to Post-Reductionist Biosemiotics. *Biosemiotics*, *13*(3), 327–346. https://doi.org/10.1007/s12304-020-09393-w

Herzog, M. (2009). Binding Problem. In M. D. Binder, N. Hirokawa, & U. Windhorst (Eds.), *Encyclopedia of Neuroscience* (pp. 388–391). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-29678-2_626

Hidalgo, C. A. (2015). *Why information grows : the evolution of order, from atoms to economies*. Basic Books.

Hoffmeyer, J. (1996). *Signs of meaning in the universe*. Bloomington : Indiana University Press, [1996] ©1996.

Jablonka, E. (2002). Information: Its Interpretation, Its Inheritance, and Its Sharing. *Philosophy of Science*, *69*(4), 578–605. https://doi.org/10.1086/344621

Keegstra, J. M., Carrara, F., & Stocker, R. (2022). The ecological roles of bacterial chemotaxis. *Nature Reviews Microbiology*, *20*(8), 491–504. https://doi.org/10.1038/s41579-022-00709-w

Koch, C. (2004). *The Quest for Consciousness - A Neurobiological Approach*. Roberts and Company Publishers.

Kolchinsky, A., & Wolpert, D. H. (2018). Semantic information, autonomous agency and non-equilibrium statistical physics. *Interface Focus*, *8*(6), 20180041. https://doi.org/doi:10.1098/rsfs.2018.0041

Krzanowski, R. (2023). From philosophy in science to information in nature: Michael Heller's ideas. *Philosophical Problems in Science (Zagadnienia Filozoficzne w Nauce)*(75), 83–105. https://doi.org/10.59203/zfn.75.680

Kull, K. (1998). On semiosis, umwelt, and semiosphere. *Semiotica*, *120*, 299–310.

LeCun, Y. (2022). A path towards autonomous machine intelligence. https://openreview.net/forum?id=BZ5a1r-kVsf.

Lloyd, S. (2006). *Programming the Universe*. New York: Alfred A. Knopf.

Lyon, P. (2015). The cognitive cell: bacterial behavior reconsidered. *Frontiers in Microbiology*, *6*, 264. https://doi.org/10.3389/fmicb.2015.00264

Marshall, S. M., Murray, A. R. G., & Cronin, L. (2017). A probabilistic framework for identifying biosignatures using Pathway Complexity. *Philos Trans A Math Phys Eng Sci*, *375*(2109). https://doi.org/10.1098/rsta.2016.0342

Miller, S. L. (1953). A Production of Amino Acids Under Possible Primitive Earth Conditions. *Science*, *117*(3046), 528–529.

https://doi.org/doi:10.1126/science.117.3046.528

Miller, W. B., Baluška, F., Reber, A. S., & Slijepčević, P. (2025). Biological mechanisms contradict AI consciousness: The spaces between the notes. *Biosystems*, *247*, 105387. https://doi.org/https://doi.org/10.1016/j.biosystems.2024.105387

Miller, W. B., Baluška, F., & Torday, J. S. (2020). Cellular senomic measurements in Cognition-Based Evolution. *Progress in Biophysics and Molecular Biology*, *156*, 20–33. https://doi.org/https://doi.org/10.1016/j.pbiomolbio.2020.07.002

Miller, W. B., Jr. (2013). The Microcosm within the Microcosm within Evolution and Extinction in the Hologenome.

Miller, W. B., Jr. (2016). Cognition, Information Fields and Hologenomic Entanglement: Evolution in Light and Shadow. *Biology*, *5*(2), 21.

Miller, W. B., Jr. (2018). Biological information systems: Evolution as cognition-based information management. *Progress in Biophysics and Molecular Biology*, *134*, 1–26. https://doi.org/https://doi.org/10.1016/j.pbiomolbio.2017.11.005

Miller, W. B., Jr. (2023). *Cognition-Based Evolution: Natural Cellular Engineering and the Intelligent Cell* (1st ed.). CRC Press. https://doi.org/https://doi.org/10.1201/9781003286769

Miller, W. B., Jr., & Torday, J. S. (2018). Four domains: The fundamental unicell and Post-Darwinian Cognition-Based Evolution. *Progress in Biophysics and Molecular Biology*, *140*, 49–73. https://doi.org/https://doi.org/10.1016/j.pbiomolbio.2018.04.006

Pappas, S. (2020). Human-Made Stuff Now Outweighs All Life on Earth. *Scientific American*. Retrieved April 8, 2023, from

Pattee, H. H. (2012). Evolving Self-reference: Matter, Symbols, and Semantic Closure. In H. H. Pattee & J. Rączaszek-Leonardi (Eds.), *Laws, Language and Life - Howard Pattee's classic papers on the physics of symbols with contemporary commentary* (pp. 211–226). Springer. https://doi.org/10.1007/978-94-007-5161-3_11

Pattee, H. H. (2013). Epistemic, Evolutionary, and Physical Conditions for Biological Information [journal article]. *Biosemiotics*, *6*(1), 9–31. https://doi.org/10.1007/s12304-012-9150-8

Peirce, C. S. (1931–36). *The Collected Papers. Volumes 1–6*. Harvard University Press.

Peirce, C. S. (1958). *The Collected Papers. Volumes 7 & 8*. Harvard University Press.

Peters, J. D. (1988). Information: Notes Toward a Critical History. *Journal of Communication Inquiry*, *12*, 9–23.

Reber, A. S., & Baluška, F. (2021). Cognition in some surprising places. *Biochemical and Biophysical Research Communications*, *564*, 150–157. https://doi.org/https://doi.org/10.1016/j.bbrc.2020.08.115

Reber, A. S., Baluska, F., & Miller, W. (2023). *The Sentient Cell: The Cellular Foundations of Consciousness*. Oxford University Press. https://doi.org/10.1093/oso/9780198873211.001.0001

Rovelli, C. (2018). Meaning and Intentionality = Information + Evolution. In A. Aguirre, B. Foster, & Z. Merali (Eds.), *Wandering Towards a Goal: How Can Mindless Mathematical Laws Give Rise to Aims and Intention?* (pp. 17–27). Springer International Publishing. https://doi.org/10.1007/978-3-319-75726-1_3

Sagan, C. (1997). *The Demon-haunted World: Science As a Candle in the Dark* (1st Ballantine Books ed.). Ballantine Books.

Shannon, C. E. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal*, *27*, 379–423, 623–656. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Shannon, C. E. (1956). The Bandwagon. *IRE Transactions on Information Theory*, *2*(1), 3. https://doi.org/10.1109/TIT.1956.1056774

Sharma, A., Czégel, D., Lachmann, M., Kempes, C. P., Walker, S. I., & Cronin, L. (2023). Assembly theory explains and quantifies selection and evolution. *Nature*, *622*(7982), 321–328. https://doi.org/10.1038/s41586-023-06600-9

Stonier, T. (1990). *Information and the internal structure of the universe: an exploration into information physics*. Springer-Verlag. https://doi.org/10.1007/978-1-4471-3265-3

Stonier, T. (1997). *Information and Meaning - An Evolutionary Perspective*. Springer-Verlag.

Tononi, G., Boly, M., Massimini, M., & Koch, C. (2016). Integrated information theory: from consciousness to its physical substrate. *Nature Reviews Neuroscience*, *17*(7), 450–461. https://doi.org/10.1038/nrn.2016.44

Umpleby, S. A. (2007). Physical Relationships among Matter, Energy and Information. *Systems Research and Behavioral Science*, *24*(3), 369–372.

Vedral, V. (2010). *Decoding Reality - The Universe as Quantum Information*. Oxford University Press.

Vitas, M. (2025). Towards a Possible Definition of Consciousness. *Biosystems*, *254*, 105526. https://doi.org/https://doi.org/10.1016/j.biosystems.2025.105526

Walker, S. I., Cronin, L., Drew, A., Domagal-Goldman, S., Fisher, T., Line, M., & Millsaps, C. (2020). Probabilistic biosignature frameworks. In V. S. Meadows, G. N. Arney, B. E. Schmidt, & D. J. Des Marais (Eds.), *Planetary Astrobiology* (pp. 477–503). University of Arizona. https://doi.org/10.2458/azu_uapress_9780816540068-ch018

Wheeler, J. A. (1990). *Information, Physics, Quantum: The Search for Links* Complexity, Entropy, and the Physics of Information, SFI Studies in the Sciences of Complexity, Reading, MA.

Wiener, N. (1961). *Cybernetics: or Control and Communication in the Animal and the Machine, 2nd Edition*. MIT Press.

Yockey, H. P. (2005). *Information theory, evolution, and the origin of life*. Cambridge University press.