

The interdisciplinary ontology of consciousness in multiscale neuroscience

Alfredo Pereira Júnior

Researcher of the National Council of Scientific Research (CNPQ), State University of São Paulo Júlio Mesquita Filho (UNESP/Botucatu) Botucatu, SP - Brazil.

*Correspondence: alfredo.pereira@unesp.br

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Abstract

According to the Interdisciplinary Ontology called "Triple Aspect Monism" (TAM), consciousness has three necessary - and conjointly sufficient - aspects: Matter, Information and Sentience. All three equally derive from a 'neutral' basis - one that is neither physical nor mental - called *Energy*. Matter is *particle-condensed Energy*; Information is the differential distribution of Energy in *Space*, and Sentience (defined as "the capacity of feeling") is a special type of distribution of Energy in *Time*. Although the three aspects are potentially present in Energy, their conjunction, generating conscious experiences, occurs only - as far as we know - in living systems. In these systems, the three aspects are integrated during the evolutionary process; they develop the "first-person perspective" proper to each singular conscious being, arising from a self-organization process (the "endogenous feedback"), which, in humans, allows the emergence of self-referential meaningful language. While Matter and Information are well treated by natural and computational sciences, the understanding of Sentience, with its special temporal waveforms, poses challenges, for which a new science - called *Sentiomics* was formulated. Two compatible explanations are provided here, for the emergence of Sentience: 1) As a Fibonacci-like pattern of amplitude modulation of multi-ionic waves in time, and 2) As a quantum geometric constraint operating in dynamic organic systems and projecting conscious contents.

Keywords: Ontology, consciousness, multiscale neuroscience, aspect monism, Energy, Information, Sentience

1. Introduction

Philosophies of becoming, starting with Aristotle (see [Bodnar, 2012](#)), and represented in contemporary times by the work of [Whitehead \(1929\)](#), conceive reality as a set of potentialities that combine in spatiotemporal updates, generating the phenomena for us experienced and scientifically studied. This "empirical" nature, amenable to observation and experimentation, is generated by combinations and re-combinations of the potentialities of reality. The spatiotemporal outcomes compose the *states* of natural systems, and their dynamic changes, that we experience, both consciously and unconsciously.

In the interdisciplinary ontology called "Triple Aspect Monism" (TAM) ([Pereira Jr., 2012, 2014](#)). *Energy* is the 'neutral' reality, containing the potentiality for all types of evolutionary processes of nature, including mental evolutionary processes that generated the human phenomena and the human knowledge about the evolutionary processes that generated the human species. Energy is a *set of potentialities* that unfold in

space and time, projecting dimensions beyond the Euclidian space (reduced to three orthogonal dimensions) and Newtonian time (a line corresponding to Real numbers).

TAM is an ontological variant of "Neutral Monism" ([Stubenberg, 2013](#)), in which the neutral being (neither material nor mental) contains powers (called "Elementary Energy Forms" in [Pereira Jr. et al., 2016](#)) that generate the three aspects: (i) Matter, (ii) Information and (iii) Sentience (defined as "the capacity of feeling"). Such a reality is in movement and transformation; its immediate manifestation takes place in the physical aspect of reality, studied by the physical and chemical sciences. However, reality is not reduced to the physical aspect, but unfolds progressively over time, allowing the manifestation of other potentialities of Energy.

In TAM, conscious experience requires an integration of the three aspects. For reasons proper to nature, but

still not fully known by us, the integration of the aspects, generating conscious experience (for the system in which the integration occurs) is limited to living systems, with structures and functions found in neural tissues of biological individuals. In TAM, this capacity is conceived as a *reaction* to incoming information, generating *meaning* - a capacity that mechanical machines currently do not have, because they lack the biophysical medium necessary for the task. In this paper I review two hypotheses about this medium: the *Hydro-Ionic Wave* (Fernandes-de-Lima & Pereira Jr., 2016; Pereira Jr., 2017) in the astroglial network and extracellular fluid, and the *Multiscale Brain Geometry* that afford self-intending projections (Poznanski, 2025).

2. Energy and the three aspects

There is no scientific evidence for omniscient conscious systems, as the fictional “Laplace’s Demon”, in the epistemology of Physics, or an “Universal Consciousness” in Indian religious traditions and related Idealist philosophies. Unlike religious and mystical approaches, in TAM there is no transcendent being (a “God”) driving the process, but only ideals of perfection (the “First Mover” in Aristotle) *projected by ourselves* (Feuerbach, 1841; Pereira Jr., 2024a).

In the elaboration of TAM’s interdisciplinary ontology, we can use classical conceptual resources, such as the Category Theory (Aristotle, 1963; Husserl, 1913a,b; Hartmann 'apud' Petersen, 2012 & Smith, 2003) and its logical unfolding (see Simons, 2015). However, classical Set Theory, and related computational ontologies, whose first-order semantics is representable in two-dimensional diagrams, would not be adequate to represent the complexity of TAM.

The *actuality* of mind and conscious experiences only happen when certain conditions are satisfied, allowing the conjunction of the three aspects in a integrated system. In systems that are in thermodynamic equilibrium, for example, there would be no conscious experience, due to the absence of physical conditions. In redundant or random systems, there is no informational variety or signal-to-noise ratio sufficient for the Information aspect to be effective. In systems where there is no capacity to 'feel what happens', or *Sentience* (Pereira Jr. 2021a,b,c,d), there would also be no consciousness. In this way, TAM is different from *PanPsychism*, which holds that consciousness exists to some degree, however minimal, in all domains of reality.

The Being of Reality, here called *Energy*, exists eternally in the potential state. Extending the quantum concept to all processes of becoming, it is possible to say that all possibilities co-exist in “superposed” potential states in the primal *Energy*. Actualization of the potentialities is the differential activation of some possibilities, while the others remain in the potential state. The actualization process is, therefore, always partial, because there are opposite and incompatible combinations that cannot become actual together.

For each combination that is actual, there are many others that remain “recessive”. A comparison can be made with ontogenesis: while some phenotype actualizations occur during embryological development of a complex living system, many others remain recessive. This view, known as “Epigenetics”, is opposed to “Preformationism”, the scientifically falsified hypothesis that the adult morphology already exists in miniature, in the initial stages of the formation of the embryo. In the Philosophy of Consciousness, Preformationism corresponds to PanPsychism, and TAM corresponds to what has been called “PanProtoPsychism”, the claim that consciousness is potential in all of reality, depending on specific conditions to be actualized. These conditions are fulfilled, e.g., on Earth, but not on the Moon.

The most immediate actualizations of Energy occur in three aspects, Matter, Information and Sentience:

(i) Matter is particle condensed *Energy*, from subatomic scales to macroscopic bodies, forming, at an intermediate level, the chemical elements of the periodic table.

(ii) Information concerns the organization of *Energy* in space, described by the distribution function in Boltzmann's atomistic and mechanistic modeling (see Pereira Jr., 1977). A note should be added about the concept of *entropy*. *Intrinsically ordered* macrostates are characterized by “negative entropy”, an ontological state of affairs to be distinguished from *Shannon’s entropy*, which refers to the amount of information (“knowledge”) generated by these states *for a given receiver*. “Disordered” macrostates are considered, in Statistical Mechanics, as being more likely than the “ordered” ones; the increase of thermodynamic entropy is, therefore, related to an increase of probability of the distribution of Energy, from ordered to disordered macrostates. In Shannon and Weaver's model, developed by Kolmogorov and Chaitin into Complexity Theory (see Pereira Jr., 2013), the quantity

of information in the source is measured by binary choices (bits) necessary to describe an ordered state; however, the quantity of information that is effectively transmitted is relative to the receiver's uncertainty about the ordered state in the source(s). Shannon's entropy is a measure of the reduction in the receiver's uncertainty, being proportional to the receiver's average uncertainty about a type of source.

(iii) Sentience corresponds to dynamic patterns of Energy flowing in time. Not all temporal patterns are instantiations of feelings; the proposed science of *Sentiomics* (Pereira Jr., 2021a,c; Pereira Jr. & Aguiar, 2022, 2023) aims to identify, analyze, and eventually help to preserve the natural dynamic patterns (characterized by parameters of amplitude, frequency and phase modulation) that generate feelings.

Table 1 Evolutionary Ontology. Elementary Energy Forms combine to generate the three fundamental aspects of experienced reality. For each one, there is a transition.

Potential	Transitional	Actual
The Matrix of Reality: A System of Self-Organizing Elementary Energy Forms	→ Nowness, Occasion of Experience	→ Conscious Qualia and Feeling
	→ Mathematical Forms	↕ Information
	→ Quantum Processes	↕ Matter

The branching of Energy into three aspects is illustrated in **Table 1**. Therefore, *conscious experience*, which results from the conjunction of the three aspects (see Pereira Jr., 2021a,b,c,d), corresponds to temporal processes that take place in the first-person perspective, that is, the perspective of the system in which the process occurs (the living individual body). Conscious systems, which I call *persons* (term to be used for every conscious system, whether animal, plant or any other sentient system), has its own perspective of reality, resulting from the fact that the conjunction of the three aspects occurs in systems *individuated by Matter*, generating a distinction between what belongs to the system (“Self”) and what is outside (“Non-Self”).

In the human body, the material limit is *the skin*, the largest organ of our bodies. Interoceptive processes

(towards the interior of the skin) generate the *Sense of Self*, while exteroceptive processes (towards the exterior of the skin) generate the *Sense of World* (Pereira Jr., 2018). Although such a distinction is not substantial or absolute, it is valid for assigning experienced feelings and other qualitative states of consciousness (*Qualia*) to persons. One person's *Qualia* are not directly experienced by others - for example, other persons can empathize with my suffering and also suffer because of my toothache, but it doesn't result in them *having an experience of my toothache*.

We can represent the totality of possibilities of reality (that is, the potentialities of *Energy*) by means of a space of states, called – in the scientific context – the “State Space”. Following the suggestion of Brenner (2013) on the role of the concept of Energy, the elementary components of this macrosystem are the Elementary Energy Forms (EF), which combine to generate emergent states, with which we can interact empirically (Pereira Jr. et al. 2016).

By mere analogy, we can say that EFs are like the tiny strings of M-String theory (Greene, 1999). We cannot observe them directly; we perceive only their combinations, which constitute the phenomenal reality for a person. The EFs constitute *both* the *aposteriori* empirical contents (our perceptions of the forms of the objects and the matter they are made of) and the *a priori* cognitive forms (unconscious information used by our cognitive systems) that we use to develop representations in the fields of philosophy and science. This position may help us to avoid the Kantian *aporia* of Transcendental Idealism combined with Material Realism (Pereira Jr., 2018).

To avoid a “dimensional explosion”, I propose to compress the N-dimensional space using the nested fractional dimensions model, as a means of compressing information in pragmatic contexts (Traina Jr. et al., 2010; Xu et al., 2015) and as a tool for modeling overlapping aspects of reality (see Ho et al., 2015). With this resource, we can represent the qualitative dimensions of informational processes and human experiences nested in the space-time of physics, that is, we *represent the qualitative dimensions as fractional dimensions of a four-dimensional state space* (Pereira Jr. et al, 2016).

The EF that constitutes the state space of reality are conceived as eternal, remaining subjacent to all updates that occur over time. Updates, which correspond to dynamic combinations of EF, constitute the space-time,

but contain properties that are not reduced to basic physical properties. The combinations occur in three phases, here called *aspects* (see [Pereira Jr., 2013; 2014](#)). All aspects derive directly from Energy, and therefore cannot be reduced to each other. Considering their common source of being, the resulting theory is Monist, not “Trialist”, as Karl Popper’s theory of “three worlds” ([Popper, 1978](#)).

There is an order of updates: the second and third aspects depend on suitable conditions (prerequisites) to be carried out. The first aspect is an immediate update of the potentialities of Nature; it is necessary as an initial step in the process of becoming. *Energy* continues to manifest itself along the process, generating newness for those systems immersed in the process. The second aspect depends on the previous update of the first, added with the manifestation of *Energy* as distributed in *Space*. The third aspect depends on a previous update of the second, added with another manifestation of *Energy* distributed in *Time*.

I conceive the updating process as being non-deterministic, including a component of “chance” in the sense of Cournot ([Lungarzo & Pereira Jr, 2009](#)) and Debrun (see [Debrun, 1996; Batista et al., 2014](#)). Cournotian processes are semi-deterministic, that is, those in which independent causal lines interact, giving rise to an unprecedented combination of EFs, which correspond to an *emergence* process, in the sense of a pattern of organization that could not be predicted with certainty only from the previous actual (empirical) state of affairs. This is because the underlying Energy manifests itself during the whole process, providing new combinations of the EF, beyond the previous manifestations (this conception has some similarities with David Bohm’s distinction of ‘Implicate’ and ‘Explicate’ order ([Bohm, 2002](#)) without the determinism provided by his proposal of ‘hidden variables’).

In TAM, the evolution of reality is conceived as a transition from Energy potentials to actualities, not as a strict deterministic causal process in which each step derives exclusively from the previous manifest step one. A useful analogy for the above concept of strong emergence is found in generative linguistics. We can generate a potentially infinite number of new words and sentences from a finite alphabet, using a finite number of rules. Likewise, we propose that the coming-to-be of reality engenders a potentially infinite number of combinations of elementary EFs, which define both the structure/functioning of our nervous system and the contents of our phenomenal experiences. Although the

outcomes are not *absolutely* new, neither are miracles, since they derive from the eternal EFs, they are new relatively to the already manifested state of affairs. Considering that the combinations are potentially infinite, it is not possible to determine *strictu sensu* the next step from the knowledge of the previous one, *even if - hypothetically - this knowledge is complete* in regard to all previous manifestations of Energy.

The EF remain subjacent to the updates, as a substrate that allows the emergence of new combinations along the evolutionary process. Again, the comparison with human language makes sense: what we say derives as much from the alphabet and rules used, as from the words and sentences previously uttered. We can formalize this type of process as being of the Markov type with memory, generating what we called *collective relational patterns* ([Lungarzo & Pereira Jr., 2009](#)).

The immediate actualization of *Energy* potentialities takes place in the physical world. According to the standard physics model, this step requires a certain type of interaction, e.g., those described as occurring between fundamental particles. The self-organization of EF gives rise to physical forces (gravitational, strong nuclear, weak nuclear and electromagnetic). The physical processes lead to the formation of the chemical elements represented in the periodic table. Chemical elements combine to form molecules and substances, as studied by the chemical sciences. A recurrent arrangement of macromolecules gives rise to the first unicellular living systems, that is, those that present the metabolic activity studied by plant and animal cytology.

The second aspect includes both the *Aristotelian Form* (the Morphology) intrinsic to living systems and *the Form* of the signals (the Information) transmitted between physical systems. The Form/Information aspect emerges concomitantly with the biological evolutionary process. All physical particles and physical-chemical compounds have shapes (atomic configurations) and dynamic regularities, but the transmission of shapes between two or more macroscopic systems, through signaling systems (forming *languages*, initially at the molecular scale) occurs in the domain communication between *living cells*.

The debate about the nature of concepts had its peak during the medieval period. In brief, we indicate two positions, both compatible with interpretations of Aristotelian philosophy: a conception of Platonic

Universals, for which the sets referred to by the logical predicates would have an existence independent of both mind and matter; and the Nominalist approach, for the which such logical terms would be nothing more than nouns, one type of symbol used in human language. In TAM, the concepts would be none of the above, but *unconscious patterns of information*, considered to be universal to the human mind, a solution that overcomes both medieval interpretive currents.

What would be the physical and informational correlates of mental concepts? With the “informational turn” in contemporary philosophy, a new interpretative possibility is asserted, namely, the existence, independent of the conscious mind, of informational processes, reproducible in machines that operate in a non-conscious way. Based on Turing's Theory of Computation, we can design and make machines which, from a set of programmed rules (which are instantiated in their electronic circuits), operate with logical-mathematical terms provided at the machine's input (which are also instantiated in electronic circuits), perform computations (information processing), and generate results provided at the output of the machine.

With the concept of “Turing Machine” and its physical implementation in computers, there was a demonstration of the possibility of processing signals independently of consciousness. These can be regarded as unconscious mental processes (Pereira Jr., 2014). Although some influential authors understand information to be necessarily meaningful, and therefore mind-dependent, such signal processing by computers could be interpreted as being a purely syntactic process, reducible to the material and informational aspects of reality, without any feeling involved. This question highlights the need to distinguish different uses of the term “information”, such as the concept of “difference that makes a difference” attributed to Gregory Bateson.

The constituent rules of a program installed in an information-processing machine can generate many computational trajectories (i.e., curves), depending on the input signal. There would be a virtually infinite number of solutions for certain types of systems of equations (e.g., in chaotic dynamical systems, recursive equations with curves leading to “strange attractors”). Such processes establish an autonomous dynamic of information, which would not depend on external factors or states of affairs, nor on an action of the conscious mind, so that they reach stable states.

With the advent of informational theories, many authors felt impelled to explain consciousness as a mere

computational process, resulting in the so-called “Computational Theory of Mind”. Rowing against this current, we have argued that informational processes constitute an emerging aspect of reality that cannot be reduced to the physical-chemical-biological aspect, being insufficient to account for the conscious aspect. Conscious systems not only process information and assign meaning to it, but also provide a feeling about the content of the information. Therefore, to approach the nature of concepts in the TAM, it would be necessary to go beyond informational theories, to include the third aspect of reality, the feeling.

Informational processes are coupled with biological processes in multi-cellular systems. In the evolutionary process, the components of Information Theory (the source, the receiver, and the encoding of messages) are made actual in the simplest ways, in the context of the activity of living systems; only later, in the context of human evolution, they become instantiated in artifacts. The realization of informational processes allows the constitution of cognitive systems with specializations, both in biological and artificial domains; however, such systems are not necessarily conscious; according to TAM, to become conscious, it is *necessary* the manifestation of Sentience. A conscious system is basically a system capable of “sensing” (meaning both the capacity of identifying forms and making sense of them) the message carried in informational processes.

The brain that instantiates consciousness is conceived as a three-aspect system, being Material, Informational and Sentient (able of feeling) at the same time. It is not wrong to say that conscious experience depends on the workings of neural tissues (or brains), because living neural tissue is conceived as including the three aspects (Pereira Jr., 2014).

3. Implications for multiscale neuroscience

The concept of isomorphism for the relationship of brain (electromagnetic fields) and conscious (perceptual Gestalts) activities was introduced by Kohler & Held (1949), Kohler (1951), Kohler et al. (1952), and Kohler (1965). Homeomorphism is a partial isomorphism, that is, an isomorphic correspondence between elements of subsets of larger sets. The larger sets, in the case of a theory of consciousness, are those composed of conscious states and brain states.

Pereira Jr. (1997) discussed the existence of homeomorphism in the relation between the properties of stimuli and informational states of the brain, using

the theory of partial correspondences developed by [Da Costa & French \(1989\)](#). The concept of homeomorphism in theory of consciousness was discussed in a doctoral thesis supervised by Thomas Metzinger ([Fell, 2004](#)). Psychophysical laws, such as Fechner's law (which motivated the discussion of the mind-body problem in the early 20th century) refer to partial correspondences between patterns of information present in a person's conscious episodes (reporting them) and properties of objects or processes in the physical world, perceived by another person (scientific observer). Laws establish quantitative correspondences between physical properties of stimuli and properties of conscious perception reported by a cognitive agent; for experimental purposes, such reports in natural language are taken as descriptions of conscious experiences. For example, reports about the size of objects used in psychophysical experiments reveal that, although our perceptions are different from the stimuli, the differences obey a proportion, which implies the existence of *partial* isomorphisms between the properties of the stimuli and the properties of the objects consciously perceived.

Our brains do not instantiate the properties of physical objects and processes; they work with information patterns that refer to such properties. We can then see that the reliability of our perceptual processes implies some degree of isomorphism between the patterns of information instantiated in our brains and the properties of physical objects and processes. Even at the unconscious level, as for example in the representations or images formed in the primary sensory cortex cut soon after the reception of signals from the thalamus, there would already be a homeomorphic mapping of the properties of the stimuli, as in the case of retinotopic maps in the visual cortex.

Researchers working with an interdisciplinary approach use the concept of information in their approaches to the cognitive functions of the brain. Our conscious experiences are mediated by patterns of information; we do not apprehend the "things themselves". However, unlike the role of imagination in Descartes, which leads to all sorts of errors and illusions, the informational processes we use to construct our conscious episodes are quite reliable. We have reasons to believe that the message carried in informational processes gives access to the dynamic reality of the world around us; for example, when using a camera, the pattern of information recorded in the photo corresponds to the shape of the object and/or process at which the camera was pointed.

The approach to conscious processes in neuroscience implies complex methodological issues, which have not yet been fully resolved. Biological processes can include the three aspects foreseen in the TAM; but they can also be studied as physical chemistry, just as they can be studied as informational. The scientific study of conscious processes available to the biological system from a first-person perspective requires a multifaceted method, which includes reports made by the conscious system, which are necessary to communicate the contents of conscious experience to the scientific observer (i.e., to convey – as far as possible – this content to the third-person perspective).

For TAM, every conscious system is an integrated unit of three aspects ([Pereira Jr., 2014](#)). The monistic approach implies a unity in diversity, that is, the physical, informational and sentient aspects, although different, present similarities, which can be described in terms of partial isomorphisms or homeomorphisms between the dynamic forms of activity. Thus, a science of consciousness must address, in addition to the structure and dynamics of consciousness, also the non-conscious physical-chemical-biological and informational aspects, with which the conscious process is indissolubly linked.

Using terms that apply to all three aspects, such as "arousal" and "inhibition", we are referring to both biophysical aspects of brain activity (generation of action potentials) and states of consciousness (being psychologically aroused or inhibited). However, as this isomorphism is partial, it does not imply evidence for the philosophical hypothesis of the *identity* of aspects. In TAM, consciousness is conceived an emergent phenomenon from the integration of the three aspects. For instance, from a physiological perspective in excitatory states there is depolarization of the neuronal membrane (decrease in the electrical potential difference between the interior and exterior of the cell, causing a pulse that will reach other neurons) while in inhibitory states there is a hyperpolarization of the membrane (increase in potential difference between the inside and outside of the cell); both *types* of states are related to *types* of conscious experience, but neuronal excitation is not *identical* to the feeling of arousal or euphoria, and neuronal inhibition is not *identical* to sleeping or psychological depression.

If, on the one hand, the existence of similarity (but not identity) between the aspects corroborates Monism, on the other hand, the inexistence of such similarities between brain and conscious activities would be evidence for a plurality of aspects. As we can identify

numerous partial isomorphisms, then multi-aspect Monism seems to be the ontology that best fits the complexity of conscious living systems.

The occurrence of conscious integration (i.e., the spatial and temporal “binding”) of the content of specific sensory modalities in integrated episodes requires a global “hub” – as predicted in the *Global Workspace Model* by Baars (1988, 1997). When complex patterns are formed on material substrates the second aspect is present, but this is not enough for the third aspect to be actualized; something else is needed, beyond the informational properties referred by the Global Workspace theory: the existence of systems capable of *feeling* the informational messages, evaluating them according to their history and based on the evaluation to guide their actions in the environment (Pereira Jr., 2013).

The mere recording and processing of unconscious syntactic patterns of information are not enough to characterize a conscious process. In spatial and temporal terms, this unconscious processing occurs in local, restricted circuits, and on the scale of milliseconds, while conscious processing involves global processing, on the scale of seconds (see Pereira Jr. et al. (2017)).

On our planet, the path leading to the third aspect (consciousness) was the emergence of living systems and biological evolution, which would be sufficient conditions for consciousness; however, we do not yet know whether these are necessary conditions. Nonbiological systems could, in principle, develop mechanisms capable of feeling, in their singular perspective, the message carried by informational processes. If feelings are related to wave processes that affect living systems, plant cell tissue, having syncytium-like morphology, may likely be capable of forming the 'waves of Energy' corresponding to a primitive sensitivity to conditions such as ambient heat, or sound patterns.

If sentience began with plants and persists in them in a primitive way then we can interpret the evolution of neural networks in animals as giving them more powerful cognitive capacities, which in turn increase their capacity for feeling, as the formation of feelings depends on and is scaled by prior cognitive processing. In the brain and body of animals, sensing is possibly related to the formation of hydro-ionic waves in neural tissue, involving glial cells, extracellular and brain fluids, blood and muscles (Pereira Jr., 2017). The calcium waves that permeate the astrocytic network

have been proposed as the substrate that functions as a multi-connector ("Master Hub") that integrates wave patterns generated in dendritic fields in multiple local fields (Pereira Jr. & Furlan, 2009; 2010; Pereira Jr., 2014).

Recent debate on neuro-astrocytic interactions has focused on the possible functions of these calcium waves 'in vivo'. Using multiphoton microscopy, some laboratories have carried out experiments with different types of stimulation of the nervous system, to observe under what conditions astrocytic calcium waves occur. For the author of the “astrocentric hypothesis” (Robertson, 2013), astrocytes would be the end point of conscious processing, but they would not be the only neural correlates of consciousness. Correlates of consciousness must be identified in the domain of neuro-astrocytic interactions, which of course also includes neuronal activities. According to the hypothesis of Pereira & Furlan (2010), neuronal activities alone would not be conscious, but to the extent that cognitive representations instantiated in neurons are associated with feelings instantiated in the astroglial network, conscious episodes are constituted. In this way, all bodily systems that instantiate such representations and feelings would be physical correlates of consciousness.

According to TAM, all feelings, even the subtle ones, such as nostalgia and light aromas, would correspond to spatiotemporal waveforms modulated by frequency and amplitude. Different parameters of this waveform would correspond to different types of feelings. Such waves have been recorded using optical technologies such as two-photon microscopy and optogenetics (see Resendez et al., 2016). Mathematical analysis of the optical records of these waveforms is still in its infancy and could become an important area of interdisciplinary study in the future (see, for example, Smeal et al., 2012, in which wave speed is evaluated; Zheng et al, 2015, in which waves are shown to have “rich informational content”).

In computational neuroscience, it is considered that the message carried by a sequence of action potentials (spike train) is encoded in the frequency and timing of the spikes (spikes) and in the phase relationships with the triggers made by other neurons.

Tactile information, for example, is encoded in the bundle of axons that make up the somatosensory afferent nerve. For this reason, message encoding is considered a population phenomenon. In a neuronal population, some receptor neurons (‘grandmother

cells') are specialized for certain specificities, firing when the afferent signal matches those characteristics.

The information that comes from outside the nervous system, internalized in a coded way in certain syntactic patterns, reaches receptor neurons specialized in the recognition of these patterns (feature detectors). Each pattern is recognized by a specialized neuron or group of neurons, but the dendritic electric field that instantiates the pattern—the graded potential, which is modulated by amplitude in time—cannot be transmitted to other neurons via action potentials, a since they have practically the same amplitude. However, the spatiotemporal pattern instantiated in the dendrites of these neurons form local field potentials, which can be communicated to adjacent astrocytes, forming small calcium waves (Bazargani & Attwell, 2016).

These small waves interfere constructively in the astrocytic network, which, in temporal windows of 2 to 3 seconds, form global waves to the system, which instantiate feelings related to a conscious episode (Pereira Jr., 2014). The astrocytic network thus interconnects patterns instantiated by large, distributed

population of neurons, resulting in the sense of a conscious episode (e.g., "scoring a goal" is an episode whose sense is composed of several patterns, including the ball, the field, the other players, the referee, the public, etc.). Each of the patterns is instantiated in a local neuronal circuit, while the resulting sense is mediated by the hydro-ionic wave that forms in the astrocytic network, acting as a Master Hub.

The multi-connector ("hub") concept should be clarified to avoid false problems. In a "small world" network, the multi-connectors are the nodes that are linked with many other processing nodes, but they are not the only places where events happen. For example, New York is a multi-connector for traveling from New Orleans to Ottawa, but this fact does not imply that the trip takes place within New York. The same applies to the astrocyte network. It is a multi-connector for neurons, blood, extracellular fluid, and other signals that must be integrated into the process of forming feelings, but this function does not imply that neurons, blood, fluid, etc., do not actively participate in the process. The thalamus is certainly another multi-connector, but it is not specific to the formation of feelings. The thalamus is the central relay for

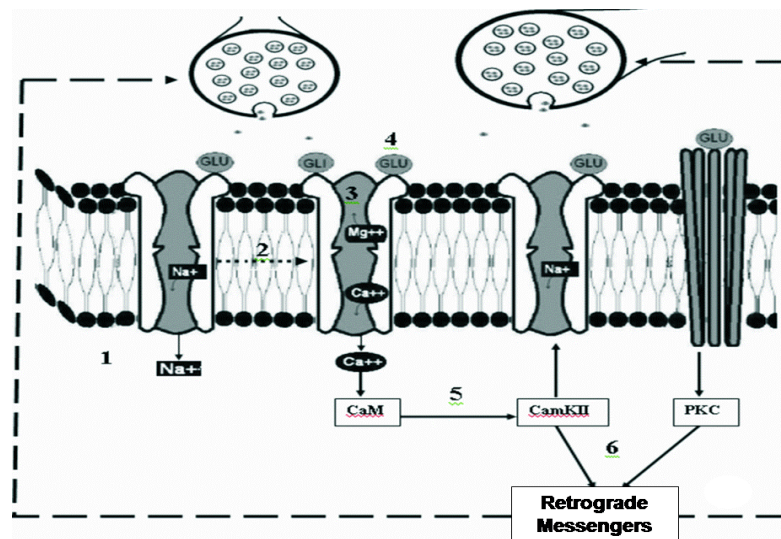


Figure 1 Mechanisms common to memory formation and consciousness: 1) Glu binding to AMPA channels, leading to Na^+ entry; 2) Membrane depolarization leading to the opening of NMDA channels; 3) Glu binding to NMDA removes Mg^{2+} blockage; 4) Glu binding to NMDA prompts Ca^{2+} entry; 5) Ca^{2+} currents entering NMDA channels activate calmodulin (CaM) that activate kinases that sustain Na^+ entry through AMPA channels and 6) There is a synergy between the calmodulin-dependent kinase and other kinases (PKC) to activate a signal transduction pathway that leads to the release of retrograde messengers (as growth factors) that reinforce the connection with the pre-synaptic neuron. These mechanisms putatively form long-term memories and associate features that may be projected to conscious experience. Copyright by APJ.

unconscious processes involved in perception and action; the astroglial network would be the multi-connector for the formation of conscious feelings.

There is no multi-connector in the neuronal network because its connections are point-to-point. Electrical synapses could do this job, but they are not numerous enough to cover the entire system, mediating an overall effect. Furthermore, there are no calcium waves in neurons, only calcium currents restricted to certain compartments. This type of process is experimentally related to long-term memory formation, not consciousness. Although both share common neuronal mechanisms (**Fig. 1**), neurons cannot form calcium waves, because they would be toxic, leading to cell apoptosis. For this reason, neurons operate with tiny membrane calcium *currents* only. Astrocytes have specialized structures to generate and propagate the calcium waves.

Neuronal action potentials are not, for the most part, generated by the entry of calcium ions, but by movements of sodium and potassium. In neurons there is a lipid membrane and directional flows that restrict the movements of ions, water molecules, blocking self-organized phenomena, such as the Belousov-Zhabotinsky reaction type. If we are studying a gas in a container, as Boltzmann did, we assume that all molecules can collide with all molecules; when they collide (interact), they are correlated. If walls are built inside the container, isolating populations of molecules, they will not be able to interact freely, and will form correlations only with their companions in the same compartment. This is what happens to ions inside a neuron; they cannot correlate with ions inside other neurons.

The brain tissue that enables a process of self-organization to support conscious activity requires a system of free interaction, as in the results found using the retina as a model of the entire brain ([Fernandes-de-Lima & Pereira Jr., 2016](#)). The conscious sense comes from the dynamic waveform instantiated in the brain tissue, with the astroglial network as the multi-connector that mediates a physical effect that boosts the emergence of a coherent state of superposition and entanglement ([Pereira Jr., 2013](#); [Pereira Jr., Vimal & Pregmolato, 2016](#)). Neurons cannot instantiate such a coherent state; they just transduce sensory information and perform cognitive processing tasks.

Calcium waves in astrocytes generate photonic fields that can be optically recorded (see, for example, [Zheng et al., 2015](#)). Neurons do not produce light; they generate dendritic electric fields restricted to individual neurons (with the exception of rare dendro-dendritic connections and electrical synapses, but one cannot build a theory of consciousness with these, as they do not densely occupy all brain tissue). Neurons also generate action potentials, composed of sequential flows of ions into and out of the membrane; this activity is unidirectional and limited by myelin; eventually, oligodendrocytes covering axons can pick up these signals and communicate them to the astrocytic network.

This type of model presupposes the existence of a dialogue between glial and neuronal networks. As mentioned earlier, neuronal dendritic fields induce small waves of calcium in adjacent astrocytes; small waves interfere and generate global waves that correspond to feelings. The process continues in the body of the conscious agent; feelings are appreciated as good, bad or neutral, according to ontogenetic patterns; the valence of feeling modulates the feedback of astroglial calcium waves in neurons, reinforcing the patterns that generated pleasant feelings, and depressing the patterns that generated unpleasant feelings ([Pereira Jr. & Furlan, 2010](#)). Such modulation would result in the selection of certain patterns for behavior, memory formation and psychosomatic effects.

An important correlation between amplitude modulation of calcium waves in astrocytes awakefulness was found. [Bojarskaitė et al. \(2019\)](#) states:

"...employed a novel activity-based algorithm to assess astrocytic Ca^{2+} signals in the barrel cortex of awake and naturally sleeping mice while monitoring neuronal Ca^{2+} activity, brain rhythms and behavior. We discovered that Ca^{2+} signaling in astrocytes exhibits distinct features across the sleep-wake cycle and is reduced in sleep compared to wakefulness. Moreover, an increase in astrocytic Ca^{2+} signaling precedes transitions from slow-wave sleep to wakefulness, with a peak upon awakening exceeding the levels during whisking and locomotion" ([Bojarskaitė et al., 2019](#), Abstract).

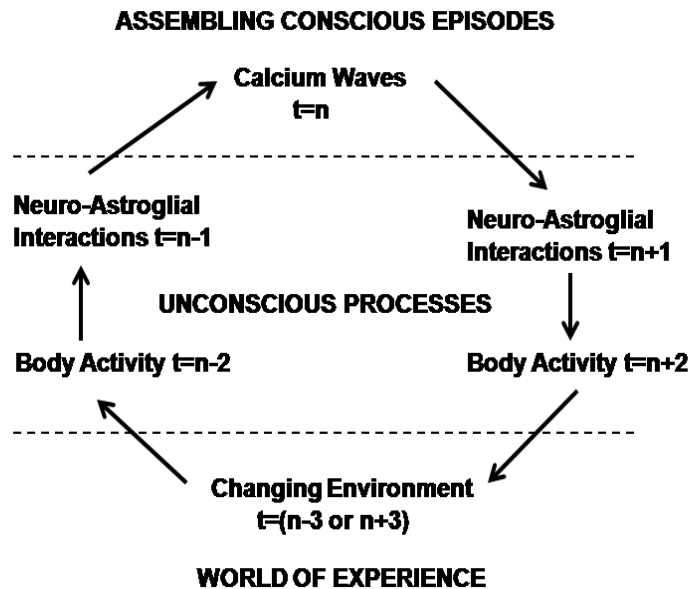


Figure 2 The Assemblage of Conscious Episodes Involves a Temporal Multiscale Cycle of Activities. Amplitude-modulated calcium waves are putatively the mark that distinguishes conscious from unconscious processes. Notation: t = time. Copyright by APJ.

Until around 2007, it seemed to most glial researchers that the astrocyte-neuron feedback would be through the release of glutamate from astrocytes into the synaptic cleft; the binding of extra glutamate with neurons would exert the modulatory function. This possibility was partially refuted in the period 2010-2015, when a "third wave" of thinking emerged (Bazargani & Atwell, 2016). A variety of calcium wave types in astrocytes and modes of propagation of this signal to the extracellular medium became evident, such as the existence of potassium channels in the astrocyte membrane activated by the calcium wave. Astrocytes also absorb potassium ions from the extracellular medium, thus indirectly controlling the timing of neuronal spike trains.

The whole temporal cycle involving the interplay of neuronal and astroglial networks, and interaction with the environment, is depicted in **Fig. 2**.

In the human species, conscious activity includes abstract thought using verbal language, which deals with concepts, thought entities typical of human consciousness. Concepts can be thought of as classes of information patterns to which our species assigns meaning and sense relatively uniformly; therefore, they would be species-specific "universals" restricted to the human mind (a discussion of this type of universal can be found in Ilario et al. 2016).

The specific features of the human species allow us to make self-referential statements, in which we explicitly refer to ourselves using verbal language. Evidence is that other species are not able to perform such an explicit self-referential operation, but considering their capacity of feeling (*Sentience*), based on the "endogenous feedback" of neuronal and glial networks, the lack of recursive language cannot be used as an argument for the absence of degrees of consciousness in their lived experiences (Carrara-Augustenberg & Pereira Jr., 2012).

4. Pereira Jr.—Poznanski controversy on sentience and 'qualia': the example of “feeling colors”

There are relevant agreements, and two main disagreements, between the above approach and the framework presented by [Poznanski \(2025\)](#). The disagreements are on the origin of the qualitative patterns ('qualia') that we consciously experience, and on the process that projects conscious phenomena. I review both disagreements and discuss how the alternative views would attempt to explain color vision.

4.1 Origin of qualitative patterns

In TAM, Sentience, the capacity for Feeling, is based on an amplitude modulated multi-ionic wave of Energy in the astroglial network and extracellular medium. It was proposed to have a special Fibonacci-like temporal waveform, as developed in [Pereira Jr., et al. \(2017\)](#). The potentiality for Feeling, that is actualized in such a Fibonacci-like waveform, is necessarily present in Energy, but in a potential state, as a combination of the Elementary Forms of Energy. This approach leads to a PanProtoPshychist view of reality, in which consciousness is in a potential state in the Being of Reality but is actualized only under special conditions.

In [Poznanski \(2025\)](#), Feelings do not arise from such Elementary Forms of Energy but are selected from quantum non-deterministic patterns. In the words of the author:

"Crucially, this emergent projective process is episodic and intermittent, not continuous, or spontaneous should not be conflated with a quantum field or an information field in the conventional Bohmian mechanics. Importantly, this framework does not align with panprotopsychism, which posits consciousness as arising from “micro-feelings,” “qualia,” or proto-conscious elements embedded ubiquitously in the universe. Instead, it proposes that intermittent quasipolaritons and their interactions form information-preserving pathways. These pathways facilitate the binding and selection of one action among competing alternatives, offering a novel framework for exploring quantum potential in intrinsic information selection." ([Poznanski, 2025](#) p. 230).

The operation that leads from quantum selection of outcomes to conscious experiences is a projective one:

"Quantum potential geometric paradigm acts as a geometric lens, organizing quantum indeterminacy and intrinsic information into structured patterns within the

brain's functional geometry. This process constitutes a geometric projection, in which raw quantum fuzziness is shaped into local coherent forms. Through this structuring, patterns of projective closure emerge, expressed as phenomenal phases of functional holonomy" ([Poznanski, 2025](#) p.235).

4.2. The process that projects conscious phenomena

The feelings experienced in the first-person perspective are closely related to the events that occur in the physical and socio-cultural context. There are in principle three ways for a conscious system to interact with the environment: (1) A physical process, corresponding to the idea of a “reflex arc”, whereby environmental stimuli initiate a physical causal process that results in a motor or endocrine response. (2) Through unconscious information processing, which consists of a “feed-forward” informational process, in which environmental stimuli are detected by specialized neurons (“feature detectors”), generating a signal that is associated with patterns already memorized (i.e., “interpreted” according to their meaning for the system), generating a distributed activation of the neuronal network (a process of signal transduction, which can be bioelectric – by means of action potentials – or biochemical – the release of neurotransmitters or neuromodulators), which converges to a behavioral response. (3) In the TAM framework, an “endogenous feedback” ([Carrara-Augustenberg & Pereira Jr., 2012](#)) or “self-referential” process (for human language), whereby ionic waves, instantiated in the astrocytic network, react on the information processing in the neuron network. *This reaction* corresponds to conscious processing, in which there is reciprocal modulation of the cognitive, sentient and enactive functions ([Pereira Jr., 2018](#)).

In [Poznanski \(2025\)](#), the recursive operation is a multiscale one, in which the whole intentional process of the agent operates on the quantum reduction process, shaping the micro-domain of activity (a type of conjecture I also raised some time ago in [Pereira Jr., 2004](#); see [Fig. 3](#)). An alternative, but not contradictory view, of the brain multiscale process generating consciousness, is articulated in [Poznanski \(2025\)](#). In this approach, the relevant factor is not hydro-ionic but a *geometric* pattern generator operating on quantum geometric phases— a manifestation of the brain's functional geometry itself, wherein curvature and intrinsic information co-evolve as a sentient processual field. Poznanski understands that spatiotemporal neuroscience, constrained by electrophysiological and field-theoretic descriptions, has so far failed to reveal

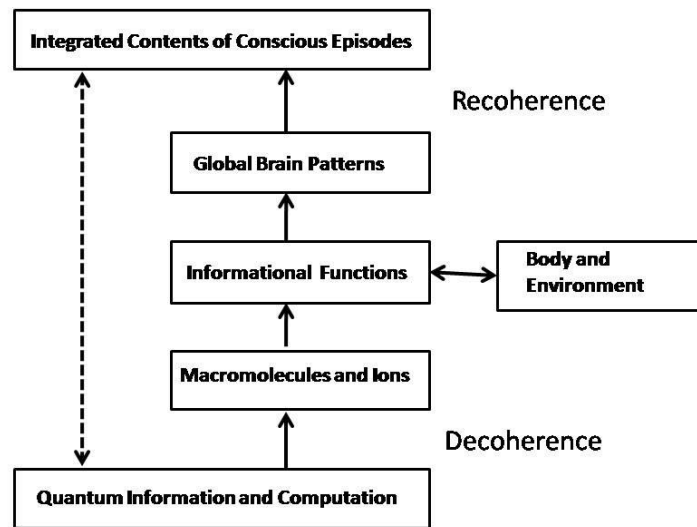


Figure 3 There is an interplay of quantum and conscious processes, crossing multiple spatial scales. Original Diagram in [Pereira Jr. \(2004\)](#). Copyright by APJ.

the geometric and processual foundations of sentience that arise (is projected by) from this intrinsic dynamic organicity.

In his framework ([Poznanski, 2025](#)), *phenomenality* is a name for the *immanent physical manifestation of intrinsic form* — a kind of *proto-experiential coherence* that precedes cognition. It is precognitive and pre-representational, rooted in the *dynamic organicity* of the brain’s functional geometry. It is not “experience of something,” but the *self-intending coherence* that later gives rise to experience. So, *phenomenality* in this sense does not refer to the conscious experiences, but to the *capacity for experience*, or to *what consciousness is made of*: the physically instantiated, self-intending coherence that becomes *experiential* when cognitively integrated. In other words, phenomenal experience is the *actualized cognition of phenomenality*. It refers to *primitive feeling* or *prehension* — an affective, pre-reflective mode of existence. So experientiality can be pre-cognitive or sub-personal, unlike “phenomenal experience,” which usually implies subjectivity and consciousness.

4.3 Discussing and eventually testing the hypotheses

According to well-known, basic neuroscience, the sequence of operations in the generation of conscious experiences begins with environmental information,

detected by a living body, followed by pattern recognition, attribution of meaning and a neural response to stimuli that modulates the ways in which the pattern of information is processed together with mechanisms of memory formation and retrieval (see [Pereira Jr. et al., 2013](#)) and adaptive behavior. In both above frameworks, establishing the endogenous feedback or intentional quantum selection over unconsciously processed information, a partial control is established over the actions, which can be performed with a degree of conscious control.

The types of shapes of feelings would be similar (partially isomorphic) to the types of shapes of temporal ionic waveforms and/or patterns of conscious projection. This type of hypothesis can be scientifically formulated and tested, using the methodological tripod used in cognitive and affective neuroscience, which consists of presenting a specific stimulus, recording multiscale brain activity and comparing brain activity patterns with the reported conscious states (evoked by the stimulus) by the subject. The biological agent is presented with a stimulus that triggers a conscious emotional reaction, generating a patterned type of feeling (for example, presentation of a figure of a venomous animal, and feeling of fear). As the agents experience and report feeling fear, their brain activity is measured using appropriate technology, revealing not only the location of the brain correlates of fear but also (and more importantly for our purposes) a

waveform or multiscale pattern that occurs simultaneously with that feeling. From this comparison, a statistically significant correlation can be found between the occurrence of fear and a certain type of waveform/pattern that characterizes brain activity during the experience of fear. Thus, although conscious experience is an emergent phenomenon that cannot be reduced to its biophysical and computational correlates, it presents correlations or partial isomorphism with certain types of biophysical/computational processes.

The concept of 'qualia' is a good example for discussing the 'unity in the diversity' implied by the TAM. and comparing it to Poznanski's geometric approach. The generation of 'qualia' involves three aspects: i) A physical qualitative pattern, which occurs in the stimulus that reaches the sensory receptors; ii) An informational pattern, in the transmission of the stimulus pattern to the central nervous system and processing in neuronal networks, and iii) The conscious experience of the physical and informational pattern for the cognitive agent, corresponding to the *reaction* of the living system to the perturbation caused by received pattern.

The three aspects of colors are: i) Physical: There is one and only one photonic waveform that - in equivalent contexts - corresponds to a color, when perceived by equivalent conscious systems endowed with appropriate receptors and bioelectric transduction mechanisms; ii) Informational: It is the pattern of organization of signals, probably specific to each biological species, which needs to be instantiated in the bioelectrical transmission to the central nervous system, in order to have the sensation of a certain color. This pattern is objective and unconscious; iii) Sentient: When affected by and reacting to the pattern, each conscious living system "feels colors" in singular ways, which can be modulated by past experiences, associating color with the sensation of heat, for example. This last aspect, the meaning attributed to color corresponds to Nagel's "what it is like to be" (Nagel, 1974).

The first two aspects are objective (or inter-subjective), but they are not arbitrary, as they are necessary for the third to occur. At the origin of the phenomenon, it is necessary to have the photonic wave (which can come in different modalities, depending on the contexts). There is a need for exposure to a particular photonic waveform for the brain to construct the conscious experience of a particular color. After the brain learns, it can reproduce the bioelectric pattern on its own, e.g.,

while dreaming. Without the reproduction of this pattern there is no perception of colors.

"Feeling colors", the *reaction* to the pattern, is restricted to consciousness; however, the informational pattern corresponding to a color, which is instantiated in the bioelectrical activity of the brain, can be detected and registered in the third-person perspective, and is not conscious. The conscious experience of colors involves the three aspects – material, informational and sentient – of a natural phenomenon. Therefore, knowing the first two aspects, which are objective (or inter-subjective), we can know something – but not everything – about the type of the singular conscious experience of a person who is seeing colors.

The color-determining waveform seen in a given part of the visual field is not simply the wave frequency reflected by a object, but the resulting shape of the interactions of all ambient light waves that reach the respective receptor on the retina. The objective, biophysical aspect of color is how the brain encodes photonic wave patterns detected by receptors in the retina and primary visual cortex.

To determine the consciously perceived color, it is necessary to take into account the patterns received by the entire receptor system, as there are reciprocal interferences. The determining form of a certain color, in a certain context – for example, red – is unconscious; *what is consciously perceived is the sense* of the red color. The "what it is like to be" *is the feeling of red*. How is the red generated in the central nervous system connected with the object that reflects light? This is where [Velmans \(2009\)](#) idea of "projection" comes in. The brain "projects" the sensed phenomenon onto the object that originated the signal.

The underlying ontological question is whether physical qualities exist in things themselves, whether they are mind-dependent or in some sense emergent in the interaction between things and conscious systems. In any case, it is necessary to distinguish between the qualities intrinsic to things (primary or secondary), and "what it is like to be", which corresponds to the conscious experience of the sensory quality, involving - in the TAM framework - a direct manifestation of *Energy* in time.

The qualities of things (such as the chemical properties of NaCl) exist in the things themselves, but subjective experience (as it is for someone to taste salt) exists in consciousness, that is, it concerns the third aspect. The use of the term 'qualia' in this context promotes

confusion, as it refers both to the quality of things (such as being salty) and to the feels one experience when tasting salty food. The bioelectric pattern of a color is objective in the sense that all biological organisms endowed with a certain type of perceptive mechanism, when focusing on a photonic wave of a certain frequency, update this pattern (colorblind people have altered mechanisms). A feeling, on the other hand, is not objective, because each organism feels what it perceives differently, or rather, there is no way to compare the feelings of the different conscious systems, except through reports, which, in turn, require a interpretation by the receiver.

In the Philosophy of Mind, when authors formulate a "thought experiment" about color, what they are manipulating in thought is the *noun* of colors, *not the felt experience* of colors. The representations (nouns of colors) cannot be confused with what is represented; a thought experiment is not with "things themselves", but with their representations. Much of the confusion about Mary (see [Jackson, 1986](#)) stems from this situation, for the reason that the fact that Mary knows the concept of red does not imply that she had the felt experience of red.

One should not look for a match between the color that is seen and an isolated pixel in the visual field; it is necessary to consider the global pattern of activation of all receptors in the retina and in the primary visual cortex, composing the so-called "contextual field". This is explained by the interference between wave frequencies, and how these interferences are picked up by the brain. The generation of the entire color spectrum from three primitive colors (red, green and blue) follows the same physical regularities. In the same way, when a color photo is taken, the film reproduces the colors resulting from the combinations of the elementary ones, according to purely physical rules.

There is contextualist assumption intrinsic to both approaches: in TAM, the astroglial ionic wave spreads to the whole brain, while Poznanski adopts a quasi-polaritonic condensate mode is spread nonlocally across macroscopic functional distances. In both, Adelson's illusion (see figure and discussion in [Pereira Jr., 2012](#)) can be explained.

In Adelson's color vision experiment, two squares in a chess board, A and B, have the same color and brightness. However, we see one of them lighter, as it is in the shadow of a cylinder, and we see the other darker, as it is exposed to greater luminosity. It is not

the brain alone that generates the illusion, but the contrast between high and low light contextual fields. This type of stimulus activates a differential gain mechanism in the cortical columns; the stimulus that is in the region of high luminosity has negative gain and appears to be darker, while the one that is in the region of low luminosity is highlighted and appears to be lighter.

In the case of visual perception, conscious color corresponds to the felt experience, which is provoked by the brain's multiscale pattern caused by the interaction of the qualitative physical properties of the stimulus (photonic field characterized by certain wavelengths) with neural systems. The pattern that is felt emerges in the relationship between the physical stimulus, our receptors, neurobiological processors and the manifestation of potentialities from Energy or Quantum Chaos.

The color that is felt is not in the objects; it's the brain, considered as a multiscale complex system, that *projects* colors onto objects, so that's where we see them. There would be a one-to-one correspondence, for singular biological individuals, between types of patterns across the perceptual field and types of consciously perceived colors. The relationship between the stimulus and the conscious response would not be arbitrary, but *diverse* in time and space, even for individuals of the same species. There are individual differences, making each conscious experience singular, even for the same person at two moments of time, departing from different initial conditions, for instance, eating the same food with hunger or previous satiation ([Pereira Jr., 2022a](#)). For different species, the mechanisms that receive and process the wave patterns change, and therefore it is likely that the feeling of the same objective patterns of a color is not the same for different species.

In [Poznanski \(2025\)](#) there is no postulation of a primary neutral source (Energy), but the consideration of quantum indeterminacy (that is, the dynamical systemic chaos generated by superposition and entanglement of particles) from which living systems select patterns, which are intentionally projected to their actions. His framework dissolves the so-called "Hard Problem" of consciousness ([Chalmers, 1995](#)) not by reducing or explaining away experience, but by eliminating the ontological split between matter and consciousness. Phenomenality is not external to physics; it is physics apprehended from within—the intrinsic expression of the brain's self-organized, dynamically organic geometry. This requires

embracing process realism, which situates the observer “inside” the unfolding dynamics, allowing one to apprehend the full system as it evolves.

Process realism provides the conceptual lens through which Quantum Potential Geometry (QPG) operates, connecting micro- and macro-scale dynamics. Phenomenality emerges from the coherent, self-intending projection of the brain’s functional geometry. QPG is not a reductionist or eliminative materialism, since it does not claim consciousness to be merely a byproduct of neurons or fields. Instead, it assumes the existence of a Material substrate, from which consciousness is emergent: QPG situates consciousness in the dynamic organicity of the brain’s functional geometry, arising from quasipolaritonic quantum-optical effects in toroidal microcavities. This is still material, but the material is structured in a way that enables phenomenality, not just computation or energy processing. Consciousness is processual, not static.

The Self-Intending Projection framework ([Poznanski, 2025](#)) emphasizes process realism, bridging Epistemology and Ontology. Consciousness is not “inside” matter; it is the emergent, self-intending dynamics of material processes—a property of how the brain’s geometry evolves and self-organizes. While QPG is grounded in physical, measurable phenomena (quantum potentials, curvature, intrinsic information), it ontologically accounts for phenomenality through self-referential loops and projective closure. That is, consciousness is real and physically instantiated, not just an epiphenomenon.

Dynamic organicity is not “conscious-less”. Just because the framework starts from material principles doesn’t mean consciousness is ignored. Rather, it emerges naturally from the constraints and interactions of material processes that are themselves structured geometrically. In short, QPG solves the Hard Problem not by positing consciousness as fundamental, but by showing how it emerges. Materialism here is not eliminative; it is a framework within which phenomenality is ontologically grounded.

5. Concluding remarks

Both approaches to Sentience and Consciousness referred in the paper do not claim phenomenal consciousness to be ontologically fundamental. For TAM, consciousness results from the integration of the 3 aspects in neural living systems; for QPG, consciousness emerges as a physically real property of structured, self-organizing brain processes.

Only epistemologically a person experiences her conscious experiences as coming first, and the mind-independent world as coming later. This is, in both frameworks, a *result* of conscious projection. Therefore, metaphysical Idealism, for both, is an artifact of the mind, erroneously considering individual conscious experience as the initial state of Reality.

Put in terms of dynamical systems theory, it can be said that the interaction between statistically independent sub-systems (that is, with degrees of freedom) expands the state space of the universe of study, since the result is not the sum, but the *product* of the possible states of the subsystems. Thus, from the interaction between physical systems, together with an actualization of the primal reality (*Energy* in TAM, quantum potential geometry in QPG), consciousness emerges.

In such a conception, the concept of ‘emergence’ that is used means the updating of possibilities; however, it is not a Laplacian-type deterministic model, as the updating of these possibilities is not assumed to be necessary, but contingent in the sense of Cournot (see [Lungarzo & Pereira Jr., 2009](#)). Such a concept of emergence is structural and diachronic in the sense of [Stephan \(1999\)](#). However, it does not seem convenient to adopt the philosophical assumptions used in this author’s approach. When characterizing Monism, he understands that nature would be constituted by systems composed of “material parts” (p. 50). In this case, information and consciousness would derive from a diachronic evolution ([Stephan, 1999](#), p. 53) that is unpredictable on the basis of the knowledge of such material parts and irreducible to them. This type of reasoning assumes that natural systems are composed exclusively of “material parts”. Besides this problem, “strong emergence” is not defined ontologically, but in terms of our incapacity of predicting the outcomes or deducing them from previous statements.

There is an important caveat to be made regarding the possible predictability and/or reducibility of such emerging aspects. This type of prediction would be of an approximate or probabilistic nature, and not of a strictly deductive nature as proposed by [Nagel \(1961\)](#) in his theory of scientific explanation. In the interaction of many subsystems, generating the global dynamics of a given complex system, the resulting state space corresponds to the product (and not the sum) of the states of the systems considered individually, which gives rise to a *combinatorial explosion* like the three-body problem in the classical physics and other problems currently discussed in the theory of chaotic dynamical systems. Small variations in the

computation of the initial state of the interacting sub-systems, and/or in the boundary conditions, can generate large variations in the possible results. Given the limitations of computational processes and considering the difficulties inherent to combinatorial processes in complex systems, for practical purposes the properties of emergent phenomena are unpredictable, and even irreducible 'a posteriori' to the properties of the parts. These limitations in the scientific explanation of complex systems hide the need for an investigation of the ontological process that leads from the primal reality to conscious experience; however, the approaches reviewed here attempt to overcome this limitation and provide a true *ontological* explanation of consciousness in the Philosophy of Neuroscience.

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