Journal of Multiscale Neuroscience

Original Research

The dynamic organicity theory of consciousness: how consciousness arises from the functionality of multiscale complexity in the material brain

Roman R. Poznanski
Integrative Neuroscience Initiative, Melbourne, Victoria, Australia 3145

Correspondence: romanrpoznanski@gmail.com
DOI: https://doi.org/10.56280/1609121701

Received 31 October 2023 Accepted 22 January 2024 Online published 30 January 2024

Abstract

The fine structure of consciousness is temporally experienced. This makes possible a dynamic organicity theory of consciousness through disunified order in the pre-, sub- and noncognitive levels of causal processes and dynamics. This multilevel approach is based on functional systems where space is implicitly grounded as changeable boundary conditions (due to organicity), and energy capture and storage under energy flow entail structuring intrinsic information (as both hidden thermodynamic energy and hidden thermodynamic information). The use of anaesthesia indicates consciousness disappears when there is an obliteration of intrinsic information within membrane protein amino acids, suggesting that quantum-thermal fluctuations of the electromagnetic field can be functional and non-vacuous. The origin of thermo-qubit syntax is derived from the principle of self-reference as the syntax of consciousness. In addition to the classical Brownian motion of macroscopically observable mean values, the negentropically derived quantum potential is an additional degree of freedom where the structuring of intrinsic information takes place by negentropic action from the microscopically random quantum-thermal fluctuations. Such functional fluctuations provide a way for intentionality to come in from spontaneous ordering, leading to path selection as an instruction to act. The resultant intentionality becomes part of information-based action when functional interactions are selected and boundary conditions change, causing interference pattern matching through temporal reorganization of informational redundancy structures (not used in functional interactions). The self-referential dynamic structures (of evolving informational holons) transform syntactic structures into experienceable forms. In comparing the interference patterns of functional interactions during restructuring informational redundancy structures, the functionality of multiscale complexity as functional systems patterns gives experienceable forms the potential to understand "meaning" by reducing uncertainty in the process of structuring intrinsic information. The self-reference principle establishes dynamical pathways from the microscale to the macroscale (this includes nonlocal pathways), in which diachronic causation and how the disunity of causal order in the redundancy creates a weak unity of consciousness through its temporal structure, which has an inferred purpose that gives rise to a sense of self.

Keywords: Material brain, natural evolution, intentionality, functional interactions, negentropic action, nonlocal pathways, dynamic organicity, consciousness, self-reference principle, anti-entropic process, classical-to-quantum analog.

1. Introduction

Biological phenomena appeal to biological structures (Herman et al., 2021) or organizations that may be seen as emergent or not explainable exclusively in physical terms. However, all biological structures implicitly depend on physical laws and assume mental states are identified with functional structures. The functional contributions of consciousness (Ludwig,2022) do not differ from functionalism if mental states have functional or causal roles independently of the structures. This allows for the "multiple realizability" of the same mental state in biological and physical structures. Physical laws postulate that all functional structures in biology, i.e., functional-structural realism, cannot be reduced or eliminated in favour of conceptual .. structures (Tononi et al., 2016). Functional structures postulate a link between functionality in the material brain and consciousness predeterminable by physical laws at a specific scale.

Edelman & Gally (2001) use of "degeneracy" effectively illustrates the spatial boundary conditions in an organism, including the brain. Degeneracy is referred to as the ability of different structural boundary conditions to perform the same function and "functional redundancy" because it does not cater as well to natural evolution via selectionism. The confusion here lies in that evolution by selectionism is focused on structural complexity and not on the complexity of informational redundancy structures that are engulfed within degeneracy yet are functional by way of their intentionality (Searle, 1983).

Functional biology differs from functionalist theories by nonimplication of causality. For instance, Global Workspace Theory (Baars, 1997), Higher-Order Thought Theory (Rosenthal, 2006) or Predictive Processing Theory (Kiverstein et al., 2022) are examples of functionalist theories of consciousness: they focus on functions proposed to be crucial for consciousness as they implement the right kind of function – independently of the causal structure. The notion of function is not self-referential and unlikely to exhibit intentionality (see Kak, 2023). It connotes the role of an identity not within the theory of action as postulated in the Searlean approach (Searle, 1983). Indeed, the "source" that starts the holon is not an infinite regress but represents a causal closure that is self-amplifying through diachronic causality. This is different from circular causality among neurons and neural masses (Freeman, 1999). However, none of the above theories implements functional interactions, so no causal effect arises from negentropic action as a negentropic force. Thus, "causality as constraint" (Juarrero, 1998) is defined in terms of thermodynamic constraints playing a role in changeable boundary conditions (due to dynamic organicity).

Viewing consciousness from a different angle by assuming time irreversibility plays a pivotal role. Time irreversibility in the brain can be formally defined uniquely through functional interactions (Chauvet, 2006). A distributed spatiotemporal system can be decomposed across spatial and temporal scales to promote functional organization. In this way, temporal processes involve functional relations where space is implicit, and time is not treated classically in terms of duration but is influenced by changeable boundary conditions or diachronically asymmetric boundary conditions. The functional organization will be affected when functional interactions at various temporal scales constrain the evolving informational holons at various spatial scales and point to a temporal structure where time becomes some general measure of the differences among the intrinsic relational realizations within a functional organization, i.e., functional relations, with each scale embedded within the other, e.g., self-referential dynamic structure as evolving informational holons.

Physical processes obey physical laws, resulting in rules that imply constraints. Whenever there are constraints on any phenomenon, there are boundary conditions. Boundary conditions refer to the necessary conditions to produce a phenomenon. If they are changeable, then it introduces a functional aspect. That is, changeable boundary conditions refer to the constraints that affect the validity of a theory or model. Changeable boundary conditions are a feature of organicity (i.e., the state of being organic). Moreover, consciousness would be impossible in non-organic artificial systems unless a functional system approach appropriately considers changeable boundary conditions through functional interactions (Chauvet, 1996).

When functional interactions are selected, they change their boundary conditions and interference pattern matching by re-organizing information redundancies (not used in functional interactions) (Pribram, 1991). Note: an action is not a thing to be moved, so nonlocal pathways entail a property of functional interactions. Functional interactions have three specific properties (Chauvet, 2004): (i) non-symmetry, (ii) non-locality and (iii) non-instantaneity. All three properties give functional systems their unique characteristics. These three properties are exhibited only in the brain by patterns in action. Moreover, functional interactions exhibit self-referential dynamical pathways that are uniquely fathomed in brains and, hence, not phenomenally equivalent in other functional systems, putting to rest the usefulness of functionalism (Cohen & Dennett, 2011). This has strong implications for rejecting functionalism and postulating why the brain differs from anything else regarding consciousness.

Functional interactions reflect on temporally asymmetric boundary conditions that exhibit structuring of intrinsic information in proteinaceous structures spread throughout the dorsolateral frontal cortex, and the frontolimbic formations of the forebrain, suggesting an abundance of functionality. This is not just thermodynamic information but intrinsic or implicit, "unconscious subcortical information" (Hurley, 1994), which is not disclosed by introspection (Phillips, 2017), but through spontaneous potentiality via the negentropically-derived quantum potential energy (Poznanski et al, 2022b), and not 'physics information' that is processed (Meijer et al., 2021). So here, hidden thermodynamic energy and hidden thermodynamic information are intertwined, and this confusion goes back to Wolfgang Koestler, who replaced 'hidden' thermodynamic energy' with 'information' (see Freeman, 2014).

The negentropically-derived quantum potential energy (containing temperature as a term) is the causal attribution of negentropic action. It is non-Bohmian because it does not originate from the atomic scale's hidden thermodynamic energy (see Poznanski et al., 2022b), but depends on the direct transfer of molecular dipole-bound delocalized electrons in protein dynamics and enzymatic activity in neuronal membranes and protein-protein interactions (cf. Boeyens 2000, 2008; Poznanski et al., 2019b; 2022a). The negentropically-deprived quantum potential is a thermo-quantum internal energy (since it has no external energy source), representing the macroscopic aggregated effect of the microscopic random quantum-thermal fluctuations (Heifetz & Cowan,2015). The origin of quantum-thermal fluctuations is an additional source of negentropic action that is not mechanical action, but that guides dipole-bound quantum-thermal fluctuations beyond molecular agitation and is derivable from nonlinear macro-quantum wave equations or dissipative Schrödinger-like equations) (Poznanski et al., 2019a, b; Poznanski et al., 2022).

The work of Poznanski et al. (2022), Alemdar et al. (2023), and Poznanski et al. (2023) assumed such functional fluctuations in protein amino acid residues where intentionality comes in from spontaneous ordering and leads to path selection as an instruction to act (without a homunculus) through nonlocal pathways. Experimental and theoretical studies have shown that it can also occur in neural dynamics at the cognitive level (cf., Tschacher et al., 2003; Haken & Tschacher, 2010; Demertzi et al., 2019). Tschacher & Haken (2007) proposed a temperature gradient dynamic in non-equilibrium systems. The studies performed by Tschacher et al. (2003), Haken & Tschacher (2010), and Tschacher & Haken (2007) use thermodynamic energy as the average kinetic energy of the system's constituent particles due to their motion, suggesting that self-organizing pattern formation is the basis of a system exhibiting intentionality.

Thermodynamic information is intricately linked to orderliness/arrangement via the thermodynamic reduction of entropy called "negentropy" (Brillouin, 1962). Léon Brillouin's concept of negentropy as thermodynamic information suggests that thermodynamic information is physical. Conveying thermodynamic information as thermo-qubit syntax from quantum-thermal fluctuations as a communication language (Brändas, 2023).

A more fundamental remark concerns the existence of the thermo-qubit as a superposition of quantum states. This reality depends on the interpretation of quantum mechanics. In the hydrodynamic analog interpretation, the wave function is insufficient to describe the quantum state completely, so the qubit does not exist. However, the conditions under which a functional system nevertheless can be described by a Schrödinger-like equation are known as this classical-to-quantum analog (cf. Lorenz et al., 2023).

This is not how "meanings" can be assigned through interference patterns using a classical brain model as no brain representations exist. In "biological semantics," often physics is used to suggest how a variety of patterns represent semantics. Often, "edge of chaos" dynamics (Sbitnev, 2024) is made. The dictum that semantic information is intrinsic to the brain is like the concept of "semantic pointer" in the computational theory of representation (Schröder et al., 2014; Blouw et al., 2016) but is not intrinsic to the brain. The idea of syntactic and semantic information stems from a theory of representations and, as such, is not proven to be a viable basis for intrinsic information.

Physical interactions exhibit the property of information exchange, information transfer and subsequently, information propagation and, ultimately, information processing in computers. Information-based action (cf., Roeder, 2003) can be diachronically causal. In other words, syntactical structures are composed of thermo-qubit syntax, which is the source of the evolving informational holons. Chomsky defines this as syntactic structures (Chomsky, 1957). Furthermore, the process of structuring intrinsic information in terms of experienceable forms that arise from transforming syntactic structures that become conscious experiences in higher stages of awareness.

The Intrinsicality Problem is the process of structuring intrinsic information through information-based action, upon re-organization of redundancy structures and comparing their interference patterns by spontaneous ordering in so far as reducing uncertainty that leads to an instruction to act in path selection. Structuralism, describing the structure of consciousness, aims to understand how various functional activities bring about temporal structures called information redundancy structures (Pribram et al. 1966), from which function selection occurs from the information redundancy structure to some other information redundancy structure, often via information-based action, reducing uncertainty upon comparing interference patterns and the potential understanding of "meaning" in the transformation of syntactic structures, as the end of structuring intrinsic information.

Consciousness comes from the Latin word for "self-awareness." According to the grandfather of consciousness studies—William James, for something to be considered conscious, it must possess intentionality (Freeman, 2019). Intentionality is a functional activity in the theory of action and an observer-independent phenomenon. This view is an extension of the Searlean position on the theory of action in intentionality (Searle, 1983), intersecting with Hurley's 'consciousness in action' metaphor (Hurley, 1998). I have avoided discussing philosophical properties of consciousness, such as qualia, as they are phenomenological in nature. Moreover, the phenomenological view of consciousness does not apply to conscious reality when considered in the context of functional-structural realism, an offshoot of structuralism without relying on introspection, which focuses on the dynamics of functional interactions in the process of selection of function. On the aspect of phenomenological consciousness, it appears like a black box of "being" instead of "doing." However, functional interactions entail self-referential dynamics that are uniquely fathomed and, hence, not phenomenally equivalent in other functional systems.

Consciousness without structure may seem more of a "*deus ex machina*" entity in its function. Structuralism focuses on objective structure consciousness or "the what of" consciousness and was first articulated by Sigmund Freud. This is done by emphasizing "conscious" as in Freudian terms of (i) preconscious, (ii) subconscious, and (iii) unconscious, and not in "cognitive" as in (i) precognitive occurs before the development of awareness, sensation, or cognition, (ii) sub-cognitive occurring below the threshold of awareness, sensation, or cognition, and (iii) noncognitive occurring without awareness, sensation, or cognition. All these categories stem from their subjective temporal structure. Also, subjectively experienced as occurring at different times enables conscious experiences to be physical and causal/functional. Making sense of the unity of consciousness requires an objective structure, something outside of the content of consciousness (Hurley, 1994, 1998).

It has been noted that the process of consciousness is not static but dynamic and labile (Walshe, 1972). This implies that consciousness and its nature can change over time and are affected by the material brain. Regarding how 'matter' turns into "meaning" dynamic interactions may be insufficient for consciousness (Parrington, 2020). This requires recognizing that the material brain cannot be a spacetime projection and that simple geometry cannot solve this problem. The decoupling of space from time falls naturally in the material brain composed of 'matter' and space, and time itself arises from the constraints imposed by the changeable boundary conditions (due to organicity). The perception of time is believed to be linear and continuous in phenomenology.

Computation in the brain considers that the material brain is not a spacetime projection because space and time are intrinsic to the brain. It simply means time has its structure in the brain. Moreover, computation in the material brain is moot on the idea of spacetime being fundamental for motivity of action as change can occur without motion. When space and time are intrinsic, they can also be self-referential. With relationalism, self-referential amplification can exist and function only as relational entities. Space and time in neuroscience remain different coordinates to which experimental observations are inferred (Buzsáki & Llinás, 2017). Thus, while temporal and spatial coordinates are jointly represented in the brain, they are dissociable or separable at the neuron level (Schonhaut et al., 2023). The "absoluteness" of space and time is not considered in the Leibnizian approach, which is relational in contrast to Newton's substantivalism, and space and time are an amenity existing independently of things. Therefore, space and time in the brain is a system of epistemic functional relations reflecting a grossly nonmetric manifold (i.e., locally Euclidean topological spaces that do not carry a metric structure). Nonmetric space refers to those concepts of space where distance is irrelevant, like in the brain.

The "Hard Problem of Consciousness" (Chalmers,1995) describes phenomenological existentialism of experience as a philosophical purview. Explaining function is the easy problem of consciousness. Consciousness is hard because it is not clear why the performance of these functions accompanies experience (Chalmers,1995). Explaining functions is insufficient, but functionality explains organicity rather than just complexity. To redefine complexity functionally and to give function not only quantity but quality and, therefore, move beyond the dictum that function is static. Using a novel functional-structural realism framework, by reexamining the concept of function from a static concept to a dynamic concept, the introduction of functional interactions where there is now structure associated with functionality in the brain, brings out the properties of the dynamic organicity of consciousness. The methodology rests on the functional system theory developed by Chauvet (1996).

2. Experienceable forms as the potential for understanding "meaning"

Most organisms exhibit intentionality and, therefore, are conscious. According to Searle (1983), intentionality is the basic mechanism of understanding. Intentionality is not a promiscuous external cue or a structural attribute, such as chemical polymerization. How does consciousness impose intentionality on objects that are not intrinsically intentional? Intentionality can be understood from two perspectives: the theory of language and the theory of action (Searle, 1983). According to the theory of action, actions that have intentionality convey instructions directed at something, since an instruction to act in path selection comes from intentionality before language. This has important implications in refuting existing theories of language that claims language is needed for conscious ness (Arbib, 2017). On the other hand, the theory of the theory of language focuses on how objects are represented through semantics in language, which is not discussed here. In linguistics, syntactical forms in language are considered intrinsic and do not inherently carry any "meaning" (Chomsky,1957). While language is often thought of as a means of communication, its primary function in humans is internal thought processing. Intentions give rise to the experience of willing as an act arising from interpreting one's thought as a cause of the act, and this is part of cognition.

Bickerton & Szathmary (2023) explain the biological basis of syntactic phenomena to be several related and interacting, but largely autonomous functions. These functions do not produce "meaning". The missing link to this puzzle was advocated by Pribram (1976), who suggested that understanding occurs in consciousness in addition to cognition. How experienceable forms convey the potential for understanding "meaning" in the process of structuring intrinsic information as an additional degree of freedom by the "self-reference principle," where part of the system can refer to the whole system is a necessary ingredient for complexity (Hempel et al., 2011). A holistic view is helpful because the contextual boundary or definition of the whole grants "meaning" to the parts contained within or composing the whole. In other words, integrated information without any potential for understanding "meaning" results in observer-relative phenomena that rely on Shannon information through symbolic processing to become semantic information. Integrated information loses the "meaning" of the individual parts to give neural syntax, defined as how neural computation is applied to the brain in cognition but not in consciousness. This concept was introduced by Buzsaki (2010). The cognitive constituents of the neural syntax can be connected by changing constellations of synaptic weights, which is achieved through the organization of cell assemblies and time-decoding neurons (Schonhaut et al., 2023).

An important distinction between syntactical information in the theory of language and linguistics, and derived syntax of consciousness from the principle of self-reference is that understanding "meaning" is not about understanding a concept, i.e., a static concept, but the structuring of intrinsic information from which experienceable forms arise that have the potential for understanding "meaning" expressed in terms of functionality. The material brain does not create representations or 'look-up' tables (Poggio, 1990) that reflect upon meanings. Moreover, the material brain experiences energy loss due to the modular organization of protein-protein interactions (Lorenz et al., 2011). This structure controls energy activity by reconstructing information redundancies by interference pattern matching. Selection becomes a functional activity of intentionality (non-vicarious functions as in functionalism, but functions that carry "meaning" through ontological characteristics of the functional system in terms of functional interactions, which are an etiological description of natural evolution). The basis for interference pattern matching of information redundancies originates at the source of evolving informational holons, which is the thermoqubit syntax for communication (Communication Simpliciter) (Brändas, 2023) at the microscale.

Is there a relationship between intentionality and consciousness? It appears that the experienceable forms are limited to the potential to understand "meaning" that arises from the causal attribution of negentropic action, with an ability to act before selection. These experienceable forms, through intentionality agency, express "meaning" directed at something from the point of view of a primitive form of awareness (Fitch, 2008). Subjective "aboutness" is a manifestation of reducing impredicative uncertainty, while "surprise" is an emotional manifestation that violates expectations and has no "aboutness". Judgments under uncertainty are surprises that involve emotions. Likewise, thinking about something is a process in cognition that invokes memory and cognitive processing, while interpreting thought as a cause of the act of experience of will are intentions for memory. However, based on a rudimentary theory of language, the experience of acting is intentionality (Searle, 1983) and forms the basis of understanding through uncertainty reduction. In the theory of action, the process of transforming syntactic structures to experienceable forms conveys the potential for understanding "meaning" (Poznanski et al., 2022), so the theory of action must be a precursor to the experience of acting in the theory of acting.

Intentionality acts within the brain as the causal attribution of negentropic action originating in far-from-equilibrium thermodynamics. An outcome of qualitative physical processes that are information-based actions (Poznanski et al., 2022a) or "neural action" distinguishes itself from neural activity (as a selected function to act) in terms of intentionality (ability to act prior to selection) in the context of subjective "aboutness", namely being for something or serving a purpose. When functional interactions are selected, boundary conditions change, matching interference patterns through a temporal re-organization of informational redundancy structures. The self-referential dynamic structure consists of evolving informational holons as the process of transforming syntactic structures to experienceable forms. The self-referential dynamic structure of evolving informational holons is syntactic structures transformed because of energy capture and storage in the presence of free energy flow (Ho, 1997).

The brain uses metabolic energy for the maintenance of homeostasis. This is not consciousness-related energy, as it would eliminate the process required for a unified consciousness; although its interruption may result in impairment of correlates of consciousness states as observed via brain imaging (see G-Guzman et al., 2024), the argument comes from a rigorous extension of thermodynamics and quantum mechanics to open-dissipative systems where quantum mechanics inserts dynamics into thermodynamics (Ingarden et al., 1997). Quantum-thermal fluctuations, when transmuted, create functional variability that results in functional fluctuations. Such functional fluctuations play a role in the process of transforming syntactic structures to experienceable forms via the self-reference principle. Here, the hidden intrinsic information is the result of negentropic gain to minimize uncertainty, suggesting that the mechanism of understanding can be thermodynamic but is not a cognitive conscious experience (Poznanski et al., 2023).

Spontaneous potentiality is the negentropically-derived quantum potential energy that realizes experienceable forms through the negentropic action. The negentropic action acted upon molecular embedded raw fluctuations or informational redundancy structures contain the potential for understanding “meaning”. The evanescent “meanings” are labile, spontaneous, and actualized when the resultant information-based action compares functional systems patterns by spontaneous ordering, reducing uncertainty, and resulting in an instruction to act. In contrast to the bottom-up approach, the top-down perception and cognition, including memory, give context to semantics. When the consciousness process becomes entwined with cognition, higher up, understanding becomes an "experience of “meaning" (Liljenström, 2011) or introspective understanding. If conscious experience is beyond its fundamental roots of intentionality to the realm of conscious cognition, then I avoid the top-down approach where intentionality is replaced by ‘intentions sensed as feelings’ (Bohm, 1989).

A self-referential dynamic structure of evolving informational holons that underlies the functionality of multiscale complexity may lead to conscious cognition, where experience is supplemented with some predictive model (Magnusdottir, 2018). But if so, would it not follow that the brain also represents uncertainty (lack of information) probabilistically, not via (cognitively) conscious sensory images? That is, one separates the notion of uncertainty from that of predictability in the formation of consciousness it depends on the transformation of experienceability to conscious experience and in cognition from experience to conscious cognition.

It is also important to note that the Intrinsicality Problem replaces the Hard Problem of Consciousness as nonexperiential consciousness made up of experienceabilies (i.e., capable of being experienced but not). The act of understanding uncertainty is the main qualifier of consciousness (Poznanski et al., 2023). The "act" here connotes the experienceable form, which is, in essence, a precursor of the experience of acting. The process entails the potential for understanding “meaning” through self-referential dynamical pathways (this includes nonlocal pathways) instead of recognizing (cf. introspection) sensory information through perceptual channels, forming the basis of understanding uncertainty without relying on memory recall. It is not “coming into existence” since quantum-thermal fluctuations are irreducible (Conrad, 1996; Poznanski & Brändas, 2020), yet the process as a whole comes “to exist” perhaps not instantaneously but appears spontaneously. Its output is intentionality as an instruction to act in path selection.

Information-based action includes intentionality through temporally re-organizing of informational redundancy structures in selecting interference patterns between intermittency spikes (Alemdar et al., 2023). The activity may look like a time-based frequency spectrum following quantum Fourier transformation but instead is the most fundamental sign of functional activity and referred to as the ‘consciousness code’, which is a temporal redundancy structure. Furthermore, the source of self is not feeling because emotional and physiological feelings belong to cognition and, therefore, are outside of consciousness per Hurley (1998). According to Gallagher (2000), the concept of self originates through the structuring of redundancies in the frontolimbic portions of the forebrain.

Husserl (1893-1917) suggests intentionality as a basic functional activity through which consciousness is experienced. This consciousness later transforms into intentions sensed as experiential feelings or experience of will. According to Mele & Moser (1994), the nature of free will originates from intentionality, and is a requirement for consciousness:

“R*emove the intentional altogether from intentional action, and you have mere behavior: brute bodily motion not unlike the movement of wind-swept sand on the shores of Lake Michigan.”*

Often, it is misleading to assume psychological processes have a causal impact. To quote Henry

Stapp: "*To have free will, you need psychological processes that have a causal impact on the physical world*". However, the mechanisms of such psychological processes have yet to be determined with precision. The top-down contextual influences are not fundamental bottom-up influences. For instance, sentience, as the capacity for feelings, or intentions sensed as feelings (Bohm, 1989), is not as fundamental as a sense of self (self-awareness). Feelings are sources of unknown experiences (Amir al., 2023). For example, the experience of the act of thinking a thought is non-felt. There are no feelings attached to the experience of the act of thinking a thought, which are internal intentions to memory, implying that intentionality is more fundamental than feelings; intentionality is intentions-in-action, i.e., the experienceability to act precedes path selection. Hurley (1998) proposed the idea of consciousness in action.

Intentionality is the fundamental process of consciousness (Freeman, 2019). How can intentionality be modeled functionally? Suppose intentionality involves the dynamics of functional relations. Therefore, earlier topological models (Prentner, 2019; Steel, 2021) are dismissed as impractical for understanding the nature of consciousness. In the material brain, temporal consciousness manifests in functional relations as a succession of functional interactions. Of importance is that functional relations are not hierarchical in time or space, as that would exclude the self-referential causal closure. Therefore, the model of hierarchical field structures (Deli, 2023) or temporospatial "nestedness" (Huang, 2023) cannot fathom a self-referential principle as part of the consciousness process.

3. Temporal re-organization of informational redundancy structures

Time consciousness is not concerned with phenomenology or the concept of temporality in the theories of Bergson, Husserl, and Heidegger. Based on their theories, time consciousness plays a crucial role in the evolution of functionality with an implied purpose or intentionality. The structure of time consciousness differs from clock time since the informational redundancy structure originates from informational uncertainty (due to massive parallel information handling), and relations in the thermodynamic arrow of entropy are also referred to as the thermodynamic arrow of time (Brändas, 2013). In addition to the thermodynamic arrow of entropy that makes timekeeping possible (Erker et al., 2017), it also implies that it is possible to have multiple timelines and interchanging possibilities of the present situation with the instruction to act in path selected as if everything is connected or occurring instantaneously. This means one can concurrently access all possible choices and timelines within a functional organization. Therefore, time consciousness contains points that happen at different times but are nevertheless instantaneous. This happens only when nonlinear time is the operationalization of time consciousness. For example, the role of the anterior insula in the function of time perception or duration perception (Craig, 2009; Naghibi et al., 2023) is due to sensing feelings, so time is perceived as a fundamental property of consciousness, and this appears to be nonlinear (Bejan,2019).

The structure of time in the brain and its role in elucidating brain-based consciousness plays a role in conscious free will (Hameroff, 2012). However, the temporal structure of consciousness in action with quantum mechanical attribution is rejected on the grounds that "quantum consciousness" relies on temporal nonlocality, sending quantum information backward in classical time. The time rate of entropy production in the material brain under far-from-equilibrium conditions is unrelated to real-time, but characteristic time (McClare, 1971), and time consciousness is irreversible, therefore, consciousness in action has a classical-to-quantum analog (cf. Lorenz et al., 2023) attribution. In a holarchical modularity where the modularity dissipation is minimized, the thermodynamic asymmetry of time in the brain, i.e., the thermodynamical nature of time, is asymmetrical and irreversible (Crecraft, 2021). The structure of time is not grounded in phenomenology (Kent & Wittmann, 2021), but time consciousness at the pre-, sub- and noncognitive levels, is conjugated to be nonlinear dynamic and therefore extended over a variety of durations.

When negentropic action is evolving at the molecular scale, the time irreversibility is "non-self-limiting," a term used to describe a condition with no inherent restrictions or boundaries, compared to linearly varying physical time intervals. As a consequence, the structure of time is multitemporal. The time irreversibility is related to the intrinsic relational realizations governing the weak stability of the dynamics of the functional organization, i.e., the time order that defines the levels of functional organization (Chauvet, 2006). Indeed, time is bound with information in an uncertainty relation (cf., Nicholson et al., 2020) where rates of entropy production are subject to a time–information uncertainty relation imposed by the "rates of change in the information content of the system". This uncertainty relation locally bounds the time that elapses before the change in the information occurs, resulting in nonlinear time.

The syntax of consciousness can be postulated to be the thermo-qubit syntax at the source of the evolving informational holons derivable from the principle of self-reference. This principle demonstrates that it imparts a thermo-qubit syntax, i.e., 'bit from it', for communication between increasingly more complex physical systems (Brändas, 2023). It is a diachronically causal action determined to be generated by negentropic action. The negentropically-derived quantum potential energy is the causal attribution of negentropic action, which is a force-free process due to negentropically-derived quantum potential energy (non-Bohmian). It varies as the square root of time, e.g., 1/√t if Brownian motion* (or thermal agitation) approximates time in the brain and that quantum-thermal fluctuations or other sources of noise give rise to apparent nonlinear time irreversibility in dissipative systems following the negentropically-derived quantum potential energy path. This assumes the use of classical-to-quantum analogs so that classicality emerges with quantum effects, as, for example, the Bohmian quantum potential from classical Brownian motion (Nelson, 1966; Tsekov, 2020).

In the dynamic organicity theory of consciousness, every changing boundary condition creates a redundancy structure (noise or fluctuation). Without redundancy, no communication is intelligible (Ashby, 1956; Hsia, 1977). Pribram et al. (1966) proposed a temporal re-organization of the informational redundancy structure in the dorsolateral frontal cortex and/or the frontolimbic portions of the forebrain. Pribram (1985) defined the comparison of informational redundancy structures in time as a measure of complexity. The approach to complexity arises from functional interactions occurring at different scales and interference patterns due to fluxes occurring at different rates due to diachronically asymmetric boundary conditions. Pribram (1991), interpreted complexity as something that informational redundancy structures can measure through a temporal comparison process. The interference pattern matching or selection among many is an instruction to act in path selection from the comparison of interference patterns of re-organized redundancy structures (not used in functional interactions). The selection process compares redundancy structures, i.e., the property of having more structure than is minimally necessary so that impairment will not prevent adequate functioning of the whole.

An evolving informational holon is part of a self-referential dynamic structure that underlies the functionality of multiscale complexity, its mechanics is not based on the work of Rosen (2012), who pioneered relational biology using category theory where the function is static. This is different from intentionality, as part of the process of consciousness in action with classical-to-quantum analog attribution. The restructuring of redundancies to select a function is an ability to act prior to selection or "intentionality". Intentionality leads to the experienceable forms as the potential to understand "meaning", which, through intentions, are a form of awareness directed at something, with an ability to act prior to selection. It originates as a causal attribution of negentropic action.

The self-referential dynamic structure of evolving informational holons cannot be hierarchical because the interconnections between informational holons form holarchies. This has plagued network neuroscience when modeling space and time or temporospatial "nestedness" as done through nested hierarchies of smaller networks combined into larger ones to yield a nested network or hierarchical structure (Sporns, 2011; Zamora-Lopez et al., 2016). The decomposition of space and time is essential for weeding out this biological structure, with the implicitness of space embedding directly constraining the structuring of information. It should be mentioned that spatial embedding imposes constraints on the networks of the brain (Stiso & Bassett, 2018), yet it was not shown, based on a multiscale structure-function organization of the brain, how functionality is affected by such spatial organization or how time may be blended with the spatial organization of the brain.

Poznanski & Brändas (2020) proposed that the self-reference principle can replace emergence and self-organization when dealing with functionality rather than structure. For example, liquidity refers to systemic qualities that cannot be deduced or predicted by understanding the causal interactions of lower levels. In the case of H_2O molecules, the liquidity of water is an emergent property. This is because the parts of the system are structural identities that give rise to the systemic properties. The lower parts of the system are not structural identities but experienceabilities. As complexity increases, it gives rise to systemic qualities distinct from the new complex configurations. These qualities result from the organization of the system's parts. However, these qualities are not emergent, as the whole is nothing

* The displacement of an ensemble of quasiparticles undergoing Brownian motion is obtained by solving the diffusion equation under appropriate boundary conditions, and this shows that the displacement varies as the square root of the time, nonlinearly

more than the sum of its parts. Nonlocal pathways can produce qualitatively novel aggregativity, leading to such new systemic qualities.

A new approach undertaken by Le Bihan (2020) disregards the material brain and instead proposes that brain function is no longer to be described in terms of absolute time but through a combined brain spacetime. This approach of a 4-dimensional brain spacetime presents a functional curvature generated by brain activity. However, their pseudo-diffusion model to propagate functional activity between network nodes seems limited to the simulation of brain connectivity across brain regions and not across scales. Indeed, they propose a functional phenomenology thesis, which claims that functional phenomenology describes and analyses processes that contribute to experiences of a certain type. Functional phenomenology can be located at the same level as phenomenological psychology (Pokropski, 2020). The multiscale approach regards time as non-absolute, incorporating a structure of time consciousness.

Intentionality manifests as a temporal structure (Fuchs, 2007). The self-referential character of experienceability entails functional relations as a succession of functional interactions. Functional interactions occur at different scales, incorporating changeable boundary conditions. The “fluidity” of states signifies changeable boundary conditions. When discussing state(s), one should have a meronymic relation, i.e., does not refer to one state but to a passing of states, which supports the fundamental view of consciousness as a process of structuring intrinsic information expressed in terms of the functionality of multiscale complexity, as functional systems patterns of experienceable forms having the potential to understand “meaning” in due process by reducing uncertainty from pattern matching as an instruction to act in path selection. Therefore, this approach does not suffer the consequences of simple self-referential systems dealing with low-level sensory and motor processing (Reggia, 2013).

4. Nonlocal pathways in between syntactic structures

The nonlocal phenomenon is prevalent in the brain, for example, long-range interactions of ions and water molecules at nanoscales affecting the propagation of action potentials (see e.g., Drapaca et al., 2020). In neuropsychiatry, Germine (1991) argued against a localist view of consciousness by positioning "synchronicity" to be the principle by which a single state is generated throughout the brain at an instance. Through his holonomic brain theory, Pribram (1991) proposed that nonlocal pathways distribute functional activity, not necessarily at the subatomic scale, but supposedly in the ionic bioplasma, e.g., electron delocalization in amino acid residues and phospholipids (Crawford et al., 2008). Referring to their neural wave equation (Gould, 1995) as a macroscopic Schrödinger-type equation is insufficient as it is for closed systems and so requires an extension to Lindblad equation based on open quantum theory. This leads to an appropriate mathematical toolkit to harness self-referential dynamics in multiscale functional systems in the material brain.

An alternative development uses functional systems theory (Chauvet, 1996, 2004). Formulating a quantum mechanical version of Chauvet's theory of functional organization through Bohm's mechanics (Bohm, 1990) requires that Bohm's nonlocal physical interactions are meaningful when compared to nonlocal functional interactions. Such nonlocality concerns diachronic causality arising from functional interactions, and it is not quantum nonlocality concerning correlations rather than causation. The self-referential dynamic structure is diachronically disunified. Unfortunately, Bohm's superluminal nonlocality (Bohm ,1952) is not multiscalar, so it cannot extend to functional interactions in the material brain.

I have chosen a functional system approach instead of a cognitive or information processing approach with information propagation across time (Revach & Salti, 2022) because intrinsic information is not transferred or processed in the brain but is structured by information-based action. In functional systems theory (Chauvet, 1996), self-referential dynamics defines evolving informational holons from microscopic to macroscopic levels. Realization relations manifest between informational holons as a holarchical modularity. The experienceable form is a transformed syntactic structure by the temporal re-organization of redundancy structures.

The functionality of the macroscale field theory of neuronal dynamics of the human brain is shaped by its geometry, as evidenced in neuroimaging studies (Pang et al., 2023). However, it ignores the functionality of multiscale complexity, implying that brain function obeys a robust structure-function coupling (Preti & Van De Ville, 2019). Functional complexity is often designated complex networks with a spatial extent and a hierarchical structure (see Zamora-Lopez et al., 2016). As a result, the parlance of graph theory and the connectome (Sporns, 2011) where Markov blanket statistically isolates states for multiscale integration (see Ramstead et al., 2021) as hierarchically "evolving" networks creating hubs, with feedback recalls back to re-entry (Edelman et al., 2011). Nevertheless, the use of feedback in neural networks is self-regulating but not self-referential and, therefore, functional complexity does not describe the functionality of multiscale complexity.

Introducing functionality of multiscale complexity not as a scale-free structural network composed of functions (McShea, 2000), but as a holarchical modularity composed of evolving informational holons and the spontaneous production of constraints that leads to selection of function is a novel approach. The causality as constraint is a position where physical laws applicable at different scales are constrained to give a complex interplay of physical laws that are compounded to a particular biological function. At the source of each evolving informational holon, the corresponding timescale of functioning that, in each moment, actualizes certain selections, holarchies, of the evolving informational holons constitutes experienceability. The point is that conscious reality may reference both conscious awareness and conscious non-awareness; such postulate presents the possible existence of free will (Mudrik et al., 2022) and further suggests the uniqueness of experience expressed by identical agents. This postulate establishes a radically different understanding of consciousness based on the principle of self-reference as the actualization of richly detailed and evolving informational holons that always retain some functional independence yet are functionally interconnected to the whole. The holistic perspective overcomes these problems by constructing a grid or coordinate system that allows every part of the whole to be understood regarding how it relates to the other parts across the scale. Treating syntactic structure at the source of the evolving informational holons as the simplest ingredients (qualities), while more complex concepts like free will become formed in “holarchies” (concrescences). Therefore, suggesting that free will is interwoven in a holarchical modular fabric of functional determinism.

Functional interactions are an etiological evolutionary account of biological purpose as an alternative organizational approach to biological teleology or assembly theory (Sharma et al., 2023). Functional interactions have a biological purpose through an intentional agency (i.e., natural evolution can be described as a continued movement towards a state of lower entropy through anti-entropic process), an alternative to a thermodynamic basis for teleological causality (Deacon & Garca-Valdecasas, 2023) or the assem

bly theory, which does not show why the performance of assemblies as a function accompanies the experience. Teleonomic determinism emphasizes that recognition and description of end-directedness do not carry a commitment to teleology as an efficient causal principle (efficient causation). However, functional organization depends on indeterministic aspects like changeable boundary conditions that lead to apparent free will brought on through functional activity. Infusing free will as a subset of intentionality, one can bring consciousness onto the cusp of existence, not through memory but through intentions-in-action as an instruction to act in path selection. Free will and the consciousness of the unconscious are intertwined. Free will requires intentionality to have consciousness (Asma, 2024).

The functional organization consists of a depositional flow of states within a holarchical modularity, with each time scale. It treats evolving informational holons as parts of a whole to be interconnected within the whole in the context of modularity. This does not correspond to the action of one evolving informational holon on another in physical space since there is a contingency of specialized functions. The action is based on self-referentiality, e.g., a Klein bottle (Rappoport, 2023), but reducing uncertainty in a multiscalar brain where modularity is common and where each time scale is encapsulated within the other within a functional organization so that time motifs and do not emerge but are dependent on the holarchical modularity. Note: Modular holarchy does not encapsulate the evolving informational holons, so it is not the same as a holarchical modularity (see **Fig. 1**). Moreover, a multiscalar approach tends to give a certain degree of autonomy to various levels of granularity, with some scales having unequal contributions due to the holarchical nature of modularity.

The location of intrinsic information is in the way, various parts of the complex system functionally interact with each other over time in so-called “functionality space” in a similar manner to the mental space of the relativistic brain (Cicurel & Nicolelis, 2015). The “functionality space” can be thought of as a phase space where the state of a system is described as a function of time. The conscious actions of a physical system like the brain are not purely classical because they consider the quantum potential energy as an additional degree of informational freedom, not localized in Euclidean spacetime.

The intrinsic relational realizations between evolving informational holons give rise to a functional organization (see **Fig.1**). Therefore, intrinsic relations realizations are epistemic relations between evolving informational holons reflecting a grossly nonmetric dynamic holarchy called holarchical modularity.
.

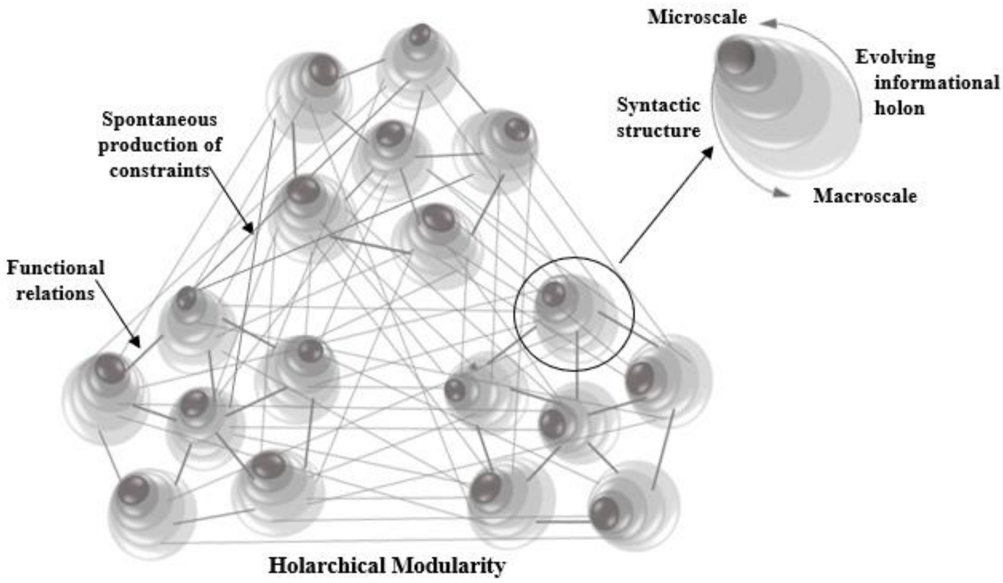

Figure 1. *The negentropic state of a functional system changing over time. Schematic illustration shows the self-referential dynamic structure of evolving informational holons that underlie the functionality of multiscale complexity (or systems patterns). The inhomogeneity of time (i.e., there are privileged moments) defines the structure of time as a system comprising intrinsic functional relations of nonlocal pathways in between evolving informational holons representing syntactic structures. They are functional relations at different temporal scales (using time scales naturally leads to space scales). There must be a discontinuity since relations between self-referential dynamical pathways are nonlocal pathways. As a result, the nonlocal phenomenon observed here and now must be deduced from what happened far away from and perhaps quite some time ago at a different level of organization. Temporospatial "nestedness" can be modeled by treating spatial scale implicitly as part of changeable boundary condition that influences time from the microscale to the macroscale. This way, time is not inferred differently from the experimental observation but is intrinsic (see Buszaki & Llinas, 2017). This makes possible self-referential characterization an important aspect of consciousness. The functional relations as a succession of functional interactions between evolving informational holons are realization relations (not causation). The functional systems patterns comprise many functional interactions, but interaction is insufficient for consciousness. When the functional interactions form a holarchical modularity by restructuring redundancies, the spontaneous ordering can give rise to negentropic action and path selection for global cohesion and subtly weak unity of consciousness. Each evolving informational holon has as a "source" (microscale) reservoir of potentialities describing the action of one syntactic structure on another, which is constraints occurring across boundary conditions and unidirectionally (non-symmetrically) to a "sink" (macroscale) representing the dynamic equilibrium. Near equilibrium path selection and causal closure continue. Causal closure means that when a type of holon ceases, all the holons they were part of within the holarchy must also cease to exist.*

Macroscale sinks amplify microscale sources into progressive ordering through diachronic causality, i.e., self-referencing causal closure. Each source to sink is a functional interaction (Chauvet, 1996).

Nested hierarchical structures are used in neuroscience to describe network organization and function in the brain (e.g., Reggia, 2013; Grindrod, 2018; Hunt, 2020; Modolo et al., 2020; Winters, 2020; Kak, 2024). They are based on the conceptualization that brains are network structures inherent in neural computation without encompassing functionality. Functionality is the qualitativeness of functioning. To infer functionality to consciousness, I refer to the qualitativeness of functioning in the brain, especially experienceability. The functionality of multiscale complexity comes into play through the nonlocal pathways. Hence, consciousness arises from the functionality of multiscale complexity at different temporal scales of functional activity. The self-referential dynamic structure of evolving informational holons transforming syntactic structures into experienceable forms because of energy capture and storage under the prevalence of free energy leads to a reduction of uncertainty and, therefore, the potential for understanding "meaning."

Consciousness disappears when there is an obliteration of intrinsic information. Hameroff (2022) conducted a study to understand the connection between consciousness and molecular systems. The study found that consciousness cannot be found in molecular systems configured by atoms with electrostatic interactions (London dispersion forces). This was also demonstrated by Hameroff (2006), who showed that anaesthesia goes to any nonpolar regions to prevent conformational dynamics in functional molecules and their interaction through London forces.

In membrane protein receptors, the dispersion London forces are the only intermolecular bonds of amino acids in hydrophobic pockets located in the interior of membrane receptor proteins, where anaesthetic agents are known to affect consciousness. This hypothesis supports the loss of consciousness during anaesthetic drugs, which affects the Van der Waals (i.e., London dispersion) forces (Hameroff, 2006, 2022). Although Hameroff (2006) reduced the analysis to protein conformation examinations via confluences of London forces, this valuable exploration requires a deeper description of the mechanism. In other words, anaesthesia increases uncertainty in the brain to a stage where intrinsic information is completely removed.

5. Thermodynamical constraints in functional systems

The brain is a non-equilibrium open system that can continuously change its boundary conditions for energy to be constrained. It results in entropy elimination to the environment and constant production of negentropic action. In the brain, all functional systems are dissipative structures with various constrictions resulting in thermodynamic constraints. The steady-state condition, $\frac{dS}{dt} = 0$, where $\frac{dS}{dt}$ is the rate of change (flux) in entropy, i.e., a perfect matching between negentropic gain and entropy production and t is the thermodynamic time (nondimensional). Is the steady-state valid in multiscalar systems with constraints? According to the second law, a system and its environment (i.e., open system) means that the entropy of the flux entering into the system from the environment, i.e., the entropy changes within the system ($\frac{dS_e}{dt}$) must equal the sum of what goes out from the system into the environment ($\frac{dS_i}{dt}$), but this disregards the constraints imposed by the functional system. Swenson (2023) suggests that spontaneous ordering occurs near equilibrium where negentropic ordered flow produces entropy at a faster rate than entropic disordered flow. It is technically an anti-entropic process (see also Del Castillo & Vera-Cruz, 2011). In addition, functional organization, which describes the dynamics of the processes associated with the functional interactions between evolving informational holons, is multi-temporal and relates to functionality of multiscale complexity. Therefore, the functionality of multiscale complexity will depend on spontaneous ordering from the evolving informational holons. Furthermore, spontaneous ordering (anti-entropic process) increases complexity by selecting self-referential dynamical pathways in evolving informational holons (and nonlocal pathways through the realization relations in holarchies), resulting in a diachronicity in functional organization due to fluxes happening at different rates due to temporarily asymmetric boundary conditions. This suggests that negative entropy flux (= negentropic gain) is greater than entropy production, and dissipation into the environment can only be measured through increases in functional organization occurring in the brain from the microscale to the macroscale. Negentropic processes are anti-entropic processes constituting manifesting from quantum-thermal fluctuations under the $\frac{dS}{dt}<0$ condition (open system). This anti-entropic process is caused by quantum-thermal fluctuations at the microscale (Conrad, 1996).

Swenson (2023) suggests that spontaneous ordering provides for an anti-entropic process as explicable when complexity increases and, as such, increases the rate of change (or flux) in entropy production within the system ($\frac{dS_e}{dt}$), which reflects as $\frac{dS_e}{dt} \geq -\frac{dS_i}{dt}$.

The second law admits $\frac{dS}{dt}, \frac{dS_i}{dt} \geq 0$. In what follows, the balance equation is

$$\frac{dS}{dt} = \frac{dS_e}{dt} + \frac{dS_i}{dt} \geq 0 \quad \text{or} \quad \frac{dS_e}{dt} \geq -\frac{dS_i}{dt} \qquad (1)$$

(***anti-entropic process***)

where $\frac{dS_e}{dt}$ is the entropy of the flux (rate of change) entering the system from the environment, and $\frac{dS_i}{dt}$ is the rate of change (or flux) in entropy production due to the irreversible processes inside the system and dissipated out from the system into the environment.

As envisaged by Swenson (2023), the fourth law of thermodynamics is that negentropic ordered flow produces entropy at a faster rate than disordered flow. If this is supported, then the negentropic gain is greater than entropic production, and then the system can be expected to select the order from disorder whenever and as soon as it gets the chance. The path selection is by the rate of change in entropy; Swenson (2023) suggests a fourth law of thermodynamics for the path taken by an open system that would maximize the entropy at the fastest rate available, given the constraints imposed on the system as defined above. The fourth law selects the distinctive interference patterns due to fluxes occurring at different rates due to diachronically asymmetric boundary conditions.

Intentionality is an instruction to act in path selection due to fluxes occurring at different rates. The outcome is that entropy production matches the negentropic gain in achieving the minimum possible entropies, which is defined as an ensemble of minima of the least entropy or a minimum uncertainty. The re-organization of redundancies reduces functional entropy and the selection of functions from various functional interactions due to changing boundary conditions. When functional entropy decreases, the re-organization of redundancies as constrained but changeable boundary conditions bring no further change, resulting in the selection of function as the mechanism that solidifies intentions-in-action into intentions. This selection mechanism acts through spontaneous ordering (Swenson, 2023). Thus, spontaneous ordering from the microscale to the macroscale is a mechanism by which negentropic action comes about. Negentropic action confers that a system is expected to select order from disorder if the ordered flow produces entropy at a faster rate than disordered flow: $\frac{dS_i}{dt} \geq -\frac{dS_e}{dt}$.

Physical interactions driven by Van der Waals forces or electrostatic interactions provide spatial constraints that form changeable boundary conditions that may not always be considered functional, depending on the dispositional state of the holarchy. Therefore, the functionality of multiscale complexity is not measured in terms of functional activity but functional entropy. So, like energy and time are a conjugate pair, the greater the energy, the shorter the time. Greater functionality of multiscale complexity leaves $\frac{dS_e}{dt} \geq -\frac{dS_i}{dt}$ through spontaneous ordering where negative entropy flux (= negentropic gain) ($\frac{dS_e}{dt}$) is greater than entropy production out of the system ($\frac{dS_i}{dt}$) and produces entropy at a faster rate. Unlike thermodynamic equilibrium, which is rapid, functional complexity of multiscale complexity takes longer to reach equilibrium.

In a non-equilibrium state, energy is stored in fluctuating motions. These fluctuating motions are active and diachronic actions. According to spontaneous ordering, negative entropy flux = negentropic gain causes negentropic action in a multiscalar dissipative sustainable system, which arises from spontaneous ordering, manifested through nonlocal pathways, to dissolve the incoming energy and resist drifting towards equilibrium to maintain or increase complexity. Time irreversibility supports the proposition that the rate of change of entropy production can only increase the open-dissipative system's complexity. A sustainable system maximizes non-dissipative energy flows while minimizing dissipative energy flows (Ho, 2015). Dissipative systems dissipate energy across scales because they stabilize far from equilibrium (Prigogine, 1978).

6. Structuring intrinsic information as a measure of functionality

Large parts of the brain are complex without any conscious happenings (Wang et al., 2018), suggesting that biological explanations of consciousness as higher-level physical features of reality must be explained in terms of unity of consciousness. How can the unity of consciousness be explained? If consciousness is necessarily unified, then a correct theory of consciousness should at least be compatible with this unity. Hurley (1994) specifies unity of consciousness as experiential events that are all associated with one center of consciousness, i.e., co-consciousness. She argues that the unity of consciousness requires objectivity outside of the contents of conscious experience. This means unity of consciousness necessitates the need for objective content. The content of conscious experience accounts for consciousness's subjective structure as part of the unity of consciousness that has no direct relationship with objective reality. Consciousness is a subjective multi-level phenomenon, where each level is functionally interconnected in the pre-, sub and noncognitive levels of causal processes. Therefore, binding the objective with the subjective is fundamentally incorrect and suggests a separation or dualism.

However, Shand (2021) provides an answer that physical should not be defined as what may be known only objectively but assumes that physical properties (structural and informational) may be known as subjectivity. Consciousness is knowable only subjectively, which results in an epistemic problem associated with physicalism when epistemic objectivism defines physicalism. For example, the neural network is part of the subjective experience, so one cannot ask objectively whether a subjective phenomenon is experiencing a subjective experience unless defining the physical as those features that can only be assessed subjectively, like quasiparticles and quantum potential energy. A good theory of consciousness must show the uniqueness of the material composition of the brain constituency.

Moreover, according to Hurley (1994), unity of consciousness can be in a state of weak unity. This stems from the disunity of information and is based on the notion that some information is "unconscious" or noncognitive and, therefore, not expressed through conscious experience. She calls such unconscious subcortical information "implicit". Degeneracy (Edelman & Gally, 2001) or "duplication" (Hurley, 1994) suggests that disunity of information brings about disunified order and the absence of unity of consciousness or so-called co-conscious. It is, therefore, suggested that the "weak unity of consciousness" is through the intrinsic relations between large numbers of evolving informational holons where functional systems patterns no longer need restructuring and reach a stable plateau. This sense is not a Nietzschean "unity" (Katsafanas, 2016) since these notions do not apply to all the relevant conscious experienceable forms. Rather, it is the sense that all these conscious experienceable forms are subsumed within a single state of consciousness by the functional organization.

The disunity of causal order gives experienceable forms the potential to understand "meaning" by interference pattern matching in the process of restructuring informational redundancy structures. Unlike liquidity that emerges from the systemic qualities of H_2O molecules (matter), the experienceabilities are interference patterns of novel aggregativity dependent on temperature but different from the liquidity of water. The most crucial aspect of this arrangement is that it can be naturally derived from thermodynamics. The quantum potential can be considered as the average energy of the informational degree of freedom (Curcuraci & Ramezani, 2019) and by associating a temperature to this energy, the application of thermodynamics to derive its form as an additional degree of freedom to the ordinary degrees of freedom of a physical system through negentropic action. Unlike the Bohmian quantum potential, the negentropically-derived quantum potential energy (Poznanski et al., 2019b; 2022a) does not go to zero for massive objects, i.e. $(\frac{\gamma}{m}) \nrightarrow 0$, as the action parameter $\gamma = n\text{h}$ where h is the Planck's constant carries a dimension of [energy][time] is much larger than Planck's constant, for a phosphorylation reaction would be $n \sim 10^{11}$ (Poznanski et al., 2022a).

Intentionality through temporal re-organization of informational redundancy structures as an instruction to act in path selection (negating the need for a homunculus) by informing the self-referential dynamic structure, composed of evolving informational holons, transforming syntactic structures into experienceable forms. The instruction to act in path selection is influenced by the rate of change in entropy manifestation of negentropic action due to negentropically-derived quantum potential energy being an attribute of negentropic action, ensuring that instructions are differentiated through a unique 'consciousness code' as a self-referential dynamic structure. Thus, eliminating the need for the question to be answered by "psychological processes" (Stapp, 2011) (or the need for a mind) being a marker of free will in recognizing the redundancy structure to delineate the functional of multiscale complexity and provide a path for reducing uncertainty. The information-based action through temporal re-organization of informational redundancy structures informs the self-reference dynamics composed of evolving informational holons as transforming syntactical structures into experienceable forms and suggests a naturalistic explanation of intentionality included reflected by matching of interference patterns between intermittency spikes (Alemdar et al., 2023) by spontaneous ordering reducing uncertainty, and that leads to path selection as an instruction to act imposed by the structuring of intrinsic information in the brain as an additional degree of freedom.

The functional organization describes the multiscale complexity through self-referential dynamical pathways. Therefore, the functionality of multiscale complexity is the patterns of the functional system will depend on experienceable forms conveying the potential for understanding "meaning", and here, it is characterized as "potential complexity." Through such interference patterns, the accretion of "potential complexity" from systems patterns of experienceable forms through nonlocal pathways is governed by intrinsic relational realizations. This is how negentropic entanglement through intrinsic relational realizations between evolving informational holons increases multiscale complexity, resulting in qualitatively novel aggregativity. The multiscale complexity is characterized by comparing informational redundancy structures that form interference patterns due to fluxes occurring at different rates due to diachronically asymmetric boundary conditions. I have suggested that time is nonlinear because it dampens the increasing entropy production and increases multiscale complexity. This suggests that multiscale complexity in the brain has a functional role that can cause qualitatively novel aggregativity at a higher scale.

According to the functional-structuralist model, the temporal re-organization of the informational redundancy structure by interference pattern matching becomes an instruction to act in path selection, providing a path for achieving minimum uncertainty, as a step towards ending the consciousness process and addressing the boundary problem (Rosenberg, 1998). Thus, a compensatory mechanism is postulated to bring about a unity of consciousness upon the actualization of memory formation (Solms, 2017). However, there is no conscious cognition without recognition, so conscious recall arises instead of memory, and only in the presence of uncertainty is memory reconsolidated (Solms, 2017). Thus, memory must compensate for uncertainty in the process of structuring intrinsic information as an additional degree of freedom.

The rate of orderliness leads to increased complexity. Including an evolved biological component dependent on selectionist principles in the brain is not due to teleonomic goal-directedness or teleonomy, as has been suggested by Igamberdiev (2024), but rather due to the functional interactions leading to functionality of multiscale complexity and its related processes. At the microscopic scale, there is no perception of time, and it is here that the structure of time originates as 'time-information uncertainty relations in thermodynamics' (cf., Nicholson et al., 2020). The structure of time in the brain is fundamentally thermodynamic and unrelated to real-time. In **Fig. 2a**, the blue curve is a typical complexity shape with time linearity, and the same plot is given by the green curve with nonlinear time. I can justify nonlinear time in the brain due to open system thermodynamics, as mentioned in Del Castillo & Vera-Cruz (2011). However, time irreversibility enables these transformations to happen when considering biological dissipative structures. By assuming the nonlinear function of time is $1/\sqrt{t}$, in **Fig. 2b,** the maximum complexity (red), say molecules in a fluid with the negentropic action (green), is like the curve as (Del Castillo & Vera-Cruz, 2011, Fig.3) that reduces the maximum complexity because of increased negentropic action. This is achieved by adding "potential complexity" to the negentropic action because of the functional systems patterns of experienceable forms.

While biophysics does not associate mental properties with the complexity of the material brain, it exhibits biological thermodynamic properties that enable a sustainable system to function under far-from-equilibrium conditions. For instance, homeostasis is maintained by metabolic energy derived from ATP dissociating to ADP. Energy from dissociation provides energy flow to maintain the body temperature at T=310 K, enabling free energy binding in proteins due to the temperature (T). The modular organization of binding proteins (Del Sol & Carbonell, 2007) results in modularity-induced entropy production (dissipation) of binding free energy, under energy flow. However, the quantum potential energy (Boeyens, 2000, 2008) is stored energy (i.e., storage of constrained energy). The importance of energy capture and storage under energy flow (Ho, 1997) adds to the possibility of both local autonomy and global cohesion within a functional organization.

This phenomenon we suggest is negentropic entanglement (Poznanski et al., 2019a). Negentropic entanglement (negentropic = relating to information gain; entanglement = binding or spread) is a contagion for spontaneous ordering (anti-entropic process) that eliminates redundancies through nonlocal pathways and, in addition, addresses the binding problem (Singer, 2001). Through negentropic entanglement, multiscale complexity increases beyond maximum complexity (Prigogine, 1978), allowing functionality to increase, representing the functionality of multiscale complexity (see **Fig. 2b,** blue curve). I postulate that negentropic entanglement allows multiscale complexity to increase beyond maximum complexity due to path selection as realization relations from each

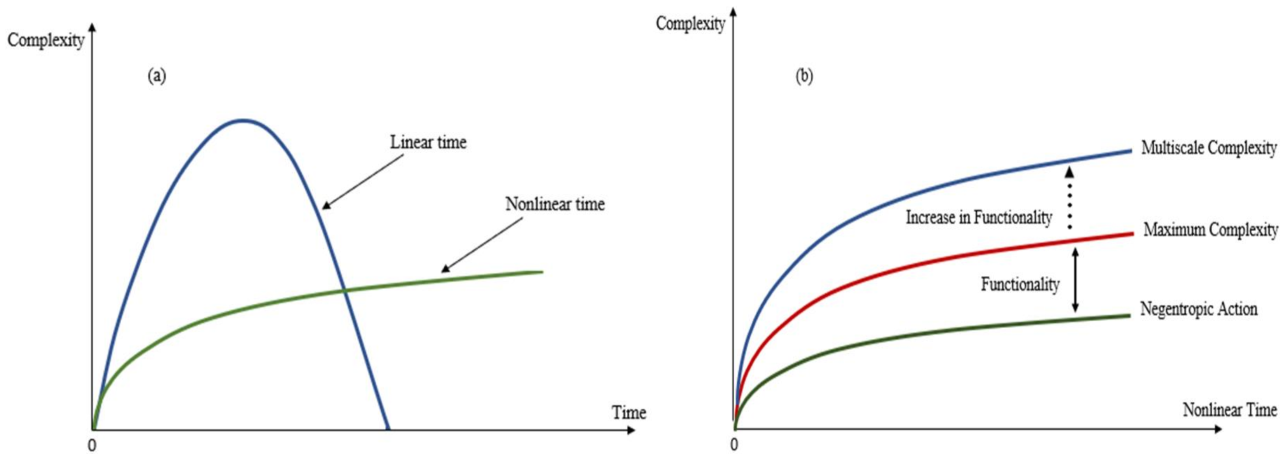

Figure 2. Functionality arising from the multiscale complexity versus nonlinear time: (a) *Schematic illustration showing complexity emerging with linear time (Blue) and nonlinear time (Green). Complexity in nonlinear time becomes an analog of a "damped" classical entropy as occurs in any biological dissipative structure, for example, molecules in the fluid (homogenous systems); (b) The addition to the maximum complexity (red) of "potential complexity" due to systems patterns of experienceable forms by the process of negentropic action (Green) reduces the maximum complexity in systems with internal constrictions (heterogenous dissipative systems) to produce qualitatively novel aggregativity,* leading to new systemic qualities expressed as *functionality. Negentropic entanglement increases maximum complexity, referred to as "multiscale complexity" (Blue), but in return, also increases functionality. This suggests that through negentropic entanglement, a unity of consciousness is made possible by the functionality of multiscale complexity.*

informational holon, thus selectively actualizing into a holarchical modularity. Therefore, binding 'representations' do not form intentions (Schröder et al., 2014), but intentions-in-action, and become intentions only when the functionality of multiscale complexity as functional systems patterns is increased through negentropic entanglement.

The functionality of multiscale complexity is functional systems patterns distributed across the brain that arise from functional activity, in which "potential complexity" aids in the consciousness process. The brain's susceptibility to noise occurs in nonpolar hydrophobic pockets of membrane receptor proteins that act as a "receptor" for consciousness to come in by spontaneous fluctuations (Li et al., 2023). A unique mechanism for actualization must be presupposed to be organic (i.e., carbon-hydrogen bonds) and increase functionality based on easier-to-change molecular binding and interaction. According to (Crawford et al., 2008), unsaturated fatty acids containing double carbon bonds exhibit coherence through conjugated bonds that form delocalized orbitals, enhancing the mobility of electrons in hydrophobic membrane regions. Conjugated bonds are the locations of delocalized electrons across phospholipids. Intramembrane proteases are enzymes that have the property of breaking up transmembrane domains of integral membrane proteins. Intramembrane proteases are enzymes with their catalytic sites within the transmembrane helices. These enzymes create an aqueous environment within the hydrophobic lipid bilayer, which has both polar and nonpolar amino acids. However, enzymatic reactions occur in the hydrophilic part of the integral membrane.

7. Conclusion

How specific brain mechanisms work to determine both the structuring of intrinsic information and the subjective access to their contents (i.e., conscious cognitive activity) has been suggested as "endogenous feedback" beyond noncognitive consciousness by Carrara-Augustenborg & Pereira (2012). This involves comprehending the functionality of multiscale complexity in terms of functional systems patterns as a whole and the selection process as consciousness in action with classical-to-quantum analog attribution.

The quantum-thermal fluctuations of the electromagnetic field can give rise to forces like Van der Waals forces. These forces contribute to the structuring of intrinsic information. Moreover, functional fluctuations play a part in the functionality of multiscale complexity by structuring intrinsic information via negentropic action in a functional system. A living negentropic state that supports biological function is a dynamic state of being organic representing an additional degree of freedom for intrinsic information to be structured, which makes it possible for a dynamic organicity theory of consciousness to take shape in the material brain.

Acknowledgment

I thank Lleuve Cacha for her help with illustrations, Alfredo Pereira Jr., Nicolangelo Iannella, Thomas Ray, Erkki Brändas, Roumen Tsekov and Jan Holmgren for discussions that guided and improved the quality of the first draft. I also thank H.G. Callaway for pointing out the work of E. Titchener, the founder of structural psychology.

Reference

Alemdar, E. Poznanski, R.R. Cacha, L.A., Leisman, G. & Brändas, E. J. (2023) New insights into holonomic brain theory: implications for active consciousness. *Journal of Multiscale Neuroscience* **2**, 159-168.

Amir, Y.Z., Assaf, Y., Yovel ,Y & Mudrik, L. (2023) Experiencing without knowing? Empirical evidence for phenomenal consciousness without access. *Cognition* **238**, 105529.

Arbib,M.A. (2017) How language evolution reshaped human consciousness. In, R.R. Poznanski, J.A. Tuszynski & T.E. Feinberg (Eds) *Biophysics of Consciousness: A Foundational Approach*. World Scientific, Singapore.

Ashby, W.R. (1956) *An Introduction to Cybernetics*. Chapman-Hall, London.

Asma, L.J.F. (2024) The relationship between free will and consciousness. *Phenomenology and the Cognitive Sciences*. **23** (*in press*).

Baars, B. J. (1997) In the theatre of consciousness: Global workspace theory, a rigorous scientific theory of consciousness. *Journal of Consciousness Studies, **4***, 292–309.

Bejan, A. (2019) Why the days seem shorter as we get older. *European Reviews* **27**, 187-194.

Bickerton, D. & Szathmary, E. (2023) *Biological Foundations and Origin of Syntax*. MIT Press, Cambr., MA.

Blouw, P., Solodkin, E.P. & Eliasmith, C. (2016) Concepts as semantic pointers: A framework and computational model. *Cognitive Sciences* **40**, 1128-1162.

Boeyens, J.C.A. (2008) The holistic molecule. In, J.C.A. Boeyens and J.F. Ogilvie (eds) *Models, Mysteries and Magic of Molecules*. Springer. Dordrecht.

Boeyens, J.C.A. (2000) Quantum potential chemistry. *South African Journal of Chemistry* **53**,49-72.

Bohm, D. (1952) A suggested interpretation of the quantum theory in terms of 'hidden variables." *Physical Review* **85**, 166-193.

Bohm, D. (1989) Meaning and information. In, P. Pylkkanen *The Search for Meaning—The New Spirit in Science and Philosophy*. Crucible Books, Swindon, UK

Bohm, D. (1990) A new theory of the relationship of mind and matter. *Philosophical Psychology* **3**, 271-286.

Brändas, E.J. (2013) Arrows of time and fundamental symmetries in chemical physics. *International Journal of Quantum Chemistry* **113**, 173–184.

Brändas, E.J. (2023) It from bit: AI and the laws of nature. *International Journal of Quantum Chemistry* 2023: e27233.

Brillouin, L. (1962) *Science and Information Theory*. Academic Press, New York.

Buzsáki, G. (2010) Neural syntax: cell assemblies, synapsembles, and readers. *Neuron* **68**,362-385.

Buzsáki, G. & Llinás, R. (2017) Space and time in the brain. *Science* **358**, 482-485.

Carrara-Augustenborg, C. & Pereira, A. Jr. (2012) Brain endogenous feedback and degrees of consciousness. In, *Consciousness: States, Mechanisms and Disorders*. A. Eugenio-Cavanna and A. Nani (Eds). Nova Science Publishers, Hauppauge, N.Y.

Chalmers, D.J. (1995) Facing up to the problem of consciousness. *Journal of Consciousness Studies* **2**,200-219.

Chauvet, G.A. (1996) *Theoretical Systems in Biology: Hierarchical and Functional Integration*. Pergamon Press, Oxford.

Chauvet, G.A. (2004) *The Mathematical Nature of the Living World: The Power of Integration*. World Scientific, Singapore.

Chauvet, G.A. (2006) On the existence of physiological age based on functional hierarchy: a formal definition related to time irreversibility. *Journal of Integrative Neuroscience* **5**, 417-442.

Chomsky,N. (1957) *Syntactic Structures*. Mouten & Co, Paris.

Cicurel, R. & Nicolelis, M.A.L. (2015) *The Relativistic Brain: How it Works and why it Cannot by Simulated by a Turing Machine*. Kios Press, Switzerland.

Cohen, M.A. & Dennett, D.C. (2011) Consciousness cannot be separated from function. *Trends in Cognitive Sciences* **15**, 358-364.

Conrad, M. (1996) Anti-entropy and the origin of initial conditions. *Chaos, Solitons & Fractals* **7**, 725-745.

Craig, A.D. (2009) Emotional moments across time: a possible neural basis for time perception in the anterior insula. *Philosophical Transactions of the Royal Society* **B364**, 1933-1942.

Crawford, M.A., Broadhurst, C.L., Galli, C., Ghebremeskel, K., Holmsen, H., Saugstad, L.F, Schmidt, W.F., Sinclair, A.J. & Cunnane, S.C. (2008) The role of docosahexaenoic and arachidonic acids as determinants of evolution and hominid brain development. In, K. Tsukamoto, T. Takeuchi, T.D.Beard and M.J. Kaiser, eds. *Fisheries for Global Welfare and Environment*. 5th World Fisheries Congress. Yokohama, Japan.

Crecraft, H. (2021) Time and causality: a thermocontextual perspective. *Entropy* **23**, 1705.

Curcuraci, L. & Ramezani, M. (2019) A thermodynamical derivation of the quantum potential and the temperature of the wave function. *Physica A* **530**, 121570.

Deacon, T.W. & García-Valdecasas, M. (2023) A thermodynamic basis for teleological causality. *Philosophical Transactions A* **381**,20220282.

Del Castillo, L. F. & Vera-Cruz, P. (2011) Thermodynamic formulation of living systems and their evolution. *Journal of Modern Physics* **2**, 379-391.

Deli, E. (2023) The thermodynamic considerations of evolution: the role of entropy in biological complexity. *Qeios Preprint*.

Del Sol, A. & Carbonell, P. (2007) The modular organization of domain structures: Insights into protein-protein binding. *PLoS Computational Biology* **3**, e239.

Demertzi, A.,Tagliazucchi, E , Dehaene, S Deco, G Barttfeld, P., Raimondo,F., Martial, C . *et al*., (2019) Human consciousness is supported by dynamic complex patterns of brain signal coordination. *Science Advances* **5**, eaat7603

Drapaca, C.S., Ozdemir, S. & Proctor, EA (2020) A non-local model of the propagation of action potentials in myelinated neurons. *Emerging Science Journal* **4**, *148-164.*

Edelman, G.M. & Gally, J.A. (2001) Degeneracy and complexity in biological systems. *Proceedings of the National Academy of Sciences (USA)* **98**, 13763-13768.

Edelman, G.M., Gally, J.A. & Baars, B.J. (2011) Biology of consciousness. *Frontiers in Psychology* **2**, 4.

Erker, P., Mitchison, M.T., Silva, R., Woods, M.P., Brunner, N. & Huber, M. (2017) Autonomous quantum clocks: Does thermodynamics limit our ability to measure time? *Physical Review X* **7**, 031022.

Fitch, W.T. (2008) Nano-intentionality: a defense of intrinsic intentionality. *Biology & Philosophy* **23**, 157-177.

Freeman, W.J. (1999) Consciousness, intentionality, and causality. *Journal of Consciousness Studies* **6**, 143-172.

Freeman, W. J. (2014) Karl H. Pribram's The Form Within: My Point of View. Book Review. *Journal of Integrative Neuroscience***13**, 429-433.

Freeman, W.J. (2019) William James on consciousness, revisited. *Chaos & Complexity Letters*, **13**, 77-96.

Fuchs, T. (2007) The temporal structure of intentionality and its disturbance in schizophrenia. *Psychopathology* **40**, 229-235.

Gallagher, S. (2000) Philosophical conceptions of the self: implications for cognitive science. *Trends in Cognitive Sciences* **4**, 14-21.

Germine, M. (1991) Consciousness and synchronicity. *Medical Hypotheses* **36**, 277-283.

Gould L. I. (1995) Quantum dynamics and neural dynamics: analogies between the formalisms of Bohm and Pribram. In, J. King and K.H. Pribram (eds.) Scale in Conscious Experience: Is the Brain Too Important To Be Left to Specialists to Study? Lawrence Erlbaum, New Jersey.

Grindrod, P. (2018) On human consciousness: A mathematical perspective. *Network Neuroscience* **2**, 23–40.

G-Guzmán,E., Sanz Perl,Y., Vohryzek,Y Escrichs, A. Manasova,D., Türker,B. *et al.* (2024) The lack of temporal brain dynamics asymmetry as a signature of impaired consciousness states. *Interface Focus* **13**, 20220086.

Haken, H. & Tschacher, W. (2010) A theoretical model of intentionality with an application to neural dynamics. *Mind & Matter* **8**, 7-18.

Hameroff, S.R. (2006) The entwined mysteries of anesthesia and consciousness. *Anesthesiology* **105**,400-412.

Hameroff, S.R. (2012) How quantum brain theory can rescue conscious free will. *Frontiers in Integrative Neuroscience* **6**, 93.

Hameroff, S.R. (2022) Consciousness, cognition, and the neuronal cytoskeleton—a new paradigm needed in neuroscience. *Frontiers in Molecular Neuroscience*, **15**,86993.5

Hempel, S. Pineda, R. & Smith, E. (2011) Self-reference as a principal indicator of complexity. *Procedia Computer Science* **6**, 22-27.

Heifetz, E. & Cohen, E. (2015) Towards a thermo-hydrodynamic-like description of Schrödinger equation via the Madelung formulation and Fisher information. *Foundations of Physics* **45**, 1514-1525.

Herman, M.A., Aiello, B.R., DeLong, J.D., Garcia-Ruiz, H., González, A.L., Hwang, W., McBeth, C., Stojković, E.A., Trakselis, M.A. & Yakoby, N. (2021) A unifying framework for understanding biological structures and functions across levels of biological organization. *Integrative and Comparative Biology* **61**, 2038–2047.

Ho, M.-W. (1997) Towards a theory of the organism. *Integrative Physiological and Behavioral Science* **32**, 343-363.

Ho, M.-W. (2015) Sustainable cities as organisms. A circular thermodynamics perspective. *International Journal of Design & Nature and Ecodynamics* **10**, 127-139.

Hsia, H.J. (1977) Redundancy: Is it the lost key to better communication? *AV Communication Review* **25**, 63-85.

Huang, Z. (2023) Temporospatial nestedness in consciousness: an updated perspective on the temporospatial theory of consciousness. *Entropy* **25**, 1074.

Hurley, S. (1994) Unity and objectivity. *Proceedings of the British Academy* **83**, 49-77.

Hurley, S. (1998) *Consciousness in Action*. Harvard University Press, Cambridge, MA.

Husserl, E. (1991) *On the Phenomenology of the Consciousness of Internal Time* (1893–1917), trans. J. B. Brough. Dordrecht: Kluwer Academic Publishers.

Hunt, T. (2020) Calculating the boundaries of consciousness in general resonance theory. *Journal of Consciousness Studies* **27**, 55-80.

Igamberdiev, A.U. (2024) Toward the relational formulation of biological thermodynamics. *Entropy* **26**,43

Ingarden, R.S. Kossakowski, A. & Ohya, M. (1997) *Information Dynamics and Open Systems: Classical and Quantum Approach*. New York: Springer Verlag.

Juarrero, A. (1998) Causality as constraint. In, *Evolutionary Systems: Biological and Epistemological Perspectives on Selection and Self-Organization*. G.Van de Vijver, S.N. Salthe & M. Delpos (Eds.) Kluwer Academic Publishers.

Kak, S. (2024) No-go theorems on machine consciousness. *Journal of Artificial Intelligence and Consciousness* (*in press*).

Katsafanas, P. (2016) *The Nietzschean Self: Moral Psychology, Agency, and the Unconscious.* Oxford University Press, Oxford.

Kent,L. & Wittmann, M. (2021) Time consciousness: the missing link in theories of consciousness. *Neuroscience of Consciousness* **7**, niab011

Kiverstein, J., Kirchhoff, M.D. & Thacker, M. (2022) An embodied predictive processing theory of pain experience. *Review of Philosophy and Psychology* **13**, 973–998.

Le Bihan, D. (2020) On time and space in the brain: a relativistic pseudo-diffusion framework. *Brain Multiphysics* **1**, 100016.

Li,A., Liu,H, Lei,X., He,Y. Wu,Q. et al. (2023) Hierarchical fluctuation shapes a dynamic flow linked to states of consciousness. *Nature Communications* **14**, 3238.

Liljenström, H. (2011) Intention and attention in consciousness dynamics and evolution. *Journal of Cosmology* **14**, 4848-4858.

Lorenz,H. , Kohler, S., Parafilo, A.., Kiselev,M. & Ludwig, S. (2023) Classical analogue to driven quantum bits based on macroscopic pendula. *Scientific Reports* **13**,18386.

Lorenz,D.M, Jeng, A. & Deem,M.W. (2011) The emergence of modularity in biological systems. *Physics in Life Sciences* **8**, 129-160.

Ludwig, D. (2022) The functional contributions of consciousness. *Consciousness & Cognition* **104**, 103383.

Magnusdottir, S. (2018) I think, therefore I think you think I am. In A.Aguirre, Foster,B & Z.Merali (Eds) Wandering Towards a Goal. Springer, Berlin.

McClare,C.W.F. (1971) Chemical machines, Maxwell's demon and living organisms. *Journal of theoretical Biology* **30**, 1-24.

McShea, D. (2000) Functional complexity in organisms: Parts as proxies. *Biology & Philosophy* **15**, 641-668.

Meijer, D.K.F., Jerman, I., Meikikh, A.V. & Sbitnev, V.I. (2021) Biophysics of Consciousness: a scale invariant acoustic information code of a superfluid quantum space guides the mental attribute. In, A. Bandyopadhyay and K. Ray (eds.), Rhythmic Oscillations in Proteins to Human Cognition, Studies in Rhythm Engineering, Springer. Springer Nature Singapore.

Mele ,A.R. & Moser, P.K. (1994) Intentional action. *Noûs* **28**, 39-68.

Modolo, J. Hassan, M. Wendling,F. & Benquet, P. (2020) Decoding the circuitry of consciousness: From local microcircuits to brain-scale networks *Network Neuroscience* **2**, 315–337.

Mudrik, L., Arie, I.G., Amir, Y., Shir, Y., Hieronymi, P. *et al*. (2022) Free will without consciousness? *Trends in Cognitive Sciences* **26**, 555-566.

Naghibi, N. Jahangiri ,N, Khosrowabadi ,R. *et al.* (2023) Embodying time in the brain: a multi-dimensional neuroimaging meta-analysis of 95 duration processing studies. *Neuropsychology Review* (*in press*).

Nelson, E. (1966) Derivation of the Schrödinger equation from Newtonian mechanics. *Physical Review* **150**, 1079-1085

Nicholson, S.B., García-Pintos, L.P., del Campo, A. & Green, J.R. (2020) Time–information uncertainty relations in thermodynamics. *Nature Physics* **16**, 1211–1215.

Pang, J.C., Aquino, K.M., Oldehinkel, M., Robinson, P.A., Futcher, B.D., Breakspear, M. & Fornito, A. (2023) Geometric constraints on human brain function. *Nature* **618**, 566-574.

Parrington, J. (2023) *Consciousness: How Our Brains Turn Matter into Meaning.* Icon Books, London.

Phillips, J.C. (2017) Hidden thermodynamic information in protein amino acid mutation tables. *Physica A* **469**, 676-680.

Poggio, T. (1990) A theory of how the brain might work. *Cold Spring Harbor Symposia on Quantitative Biology* **55**, 899-910.

Pokropski M. (2020) Phenomenology and functional analysis. A functionalist reading of Husserlian phenomenology. *Phenomenology and the Cognitive Sciences* **19**, 869–889.

Poznanski, R.R., Cacha, L.A., Latif, A.Z.A., Salleh,S.H. *et al*.(2019a) Theorizing how the brain encodes consciousness based on negentropic entanglement. *Journal of Integrative Neuroscience* **18**, 1-10.

Poznanski,R.R., Cacha, L.A., Latif, A.Z.A., Salleh, S.H. *et al*. (2019b) Molecular orbitals of delocalized electron clouds in neuronal domains. *Biosystems* **183**, 103982.

Poznanski, R.R. & Brändas, E.J. (2020) Panexperiential materialism: A physical exploration of qualitativeness in the brain. In, R.R. Poznanski and E.J. Brändas (Editors) *Quantum Boundaries of Life. Advances in Quantum Chemistry Book Series* Academic Press, London.

Poznanski, R.R., Cacha, L.A., Holmgren, J. & Brändas, E.J. (2022a) What a feeling—the underpinnings of physical feelings as molecular level holonomic effects. *Journal of Multiscale Neuroscience* **1**, 11-40.

Poznanski, R.R., Alemdar, E., Cacha, L.A., Sbitnev, V.I. & Brändas, E.J. (2022b) The activity of information in biomolecular systems: a fundamental explanation of holonomic brain theory. *Journal of Multiscale Neuroscience* **1**, 109-133.

Poznanski, R.R, Holmgren, J., Cacha, L.A, Alemdar, E. & Brändas, E.J. (2023) The act of understanding uncertainty is consciousness. *Journal of Multiscale Neuroscience* **2**, 280-291.

Pribram, K.H. (1976) Self-consciousness and intentionality. In, G.E. Schwartz et al. (eds.) *Consciousness & Self-Regulation*. Plenum Press, New York.

Pribram, K.H. (1985) Complexity and causality. In, *The Science and Praxis of Complexity*. Contributions to the symposium held at Montpellier, France. The United Nations University, Tokyo.

Pribram, K.H. (1991) *Brain and Perception: Holonomy and Structure in Figural Processing*. Lawrence Erlbaum, New Jersey.

Pribram, K. H., Lim, H., Poppen, R., & Bagshaw, M. (1966). Limbic lesions and the temporal structure of redundancy. *Journal of Comparative and Physiological Psychology*, **61**, 368–373.

Prigogine, I. (1978) Time, structure, and fluctuations. *Science* **201**, 777-785.

Prentner, R. (2019) Consciousness and topologically structured phenomenal spaces. *Consciousness & Cognition* **70**, 25-38.

Preti, M.G. & Van de Ville, D. (2019) Decoupling of brain function from structure reveals regional behavioral specialization in humans. *Nature Communications* **10**, 4747.

Ramstead, M. J. D., Kirchhoff, M. D., Constant, A., & Friston, K. J. (2021) Multiscale integration: Beyond internalism and externalism. *Synthese* **198**, 41–70.

Rapoport, D.L. (2023) Klein bottle logophysics, the primeval distinction, semiosis, perception and the topology of consciousness. In Louis H. Kauffman, Cummins, F., Dible, R. Conrad, L., Ellsbury, G., Crompton & Grote, F. Laws of Form: A Fiftieth Anniversary. World Scientific, Singapore.

Reggia, J.A. (2013) The rise of machine consciousness: studying consciousness with computational models. *Neural Networks* **44**, 112-131.

Revach, D. & Salti, M. (2022) Consciousness as the temporal propagation of information. *Frontiers in Systems Neuroscience* **16**, 759683.

Roederer, J.G. (2003) On the concept of information and its role in nature. *Entropy* **5**, 3-33.

Rosen, R. (2012) *Anticipatory Systems*. Springer, New York, New York.

Rosenberg, G. H. (1998) The boundary problem for phenomenal individuals. In, S. R. Hameroff, A. W. Kaszniak, and A. C. Scott (Eds). Toward a Science of Consciousness: The Second Tucson Discussions and Debates. Cambridge, MA, MIT Press.

Rosenthal, D.M. (2006) Consciousness and higher-order thought. In, *Encyclopedia of Cognitive Science*. John Wiley, New York.

Searle, J.R. (1983) *Intentionality*. Cambridge University Press, New York.

Sbitnev, V.I. (2024) The edge of chaos is that where consciousness manifests itself through intermittent dynamics. *Academia Biology* **2**, 13-17.

Schonhaut, D.R., Aghajan, Z.M., Kahana, M.J. & Fried, I. (2023) A neural code for time and space in the human brain. *Cell Reports* **42**, 113238.

Schröder, T., Stewart, T.C. & Thagard, P. (2014) Intention, emotion, and action: A neural theory based on semantic pointers. *Cognitive Science* **38**, 851-880.

Shand, J. (2021) Consciousness: Removing the hardness and solving the problem. *Revista Portuguesa de Filosofia* **77**, 1279-1296.

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**,321-328.

Singer, W. (2001) Consciousness and the binding problem. *Annals of the New York Academy of Science* **929**, 123-146.

Solms, M. (2017) Consciousness by surprise. In, R.R. Poznanski, J.A. Tuszynski & T.E. Feinberg (eds) *Biophysics of Consciousness: A Foundational Approach*. World Scientific, Singapore.

Sporns, O. (2011) The human connectome: A complex network. *Annuals of the New York Academy of Sciences* **929**, 109–125.

Stapp, H.P (2011) *Mindful Universe: Quantum Mechanics and the Participating Observer*. Springer, New York.

Steel, M. (2021) Modelling aspects of consciousness: a topological perspective. *Journal of Theoretical Biology* **523**, 110713.

Stiso, J. & Bassett, D.S. (2018) Spatial embedding imposes constraints on the network architectures of neural systems. *Trends in Cognitive Sciences* **22**, 1127-1141.

Swenson, R. (2023) A grand unified theory for the unification of physics, life, information and cognition (mind). *Philosophical Transactions of the Royal Society* **A381**,20220277.

Tononi G., Boly M., Massimini M., & Koch C. (2016) Integrated information theory: from consciousness to its physical substrate. *Nature Reviews Neuroscience* **17**, 450-461

Tschacher, W. & H aken, H. (2007) Intentionality in non-equilibrium systems? The functional aspects of self-organized pattern formation. *New Ideas in Psychology* **25**, 1-15.

Tschacher, W. Dauwalder, J.-P. & Haken, H. (2003) Self-organizing systems show apparent intentionality. *In, W. Tschacher & J-P. Dauwalder (eds) The Dynamical Systems Approach to Cognition. World Scientific, Singapore.*

Tsekov,R. (2020) Brownian motion and quantum mechanics. *Fluctuation and Noise Letters* **19**, 2050017

Walshe, F. M. R. (1972). The neurophysiological approach to the problem of consciousness. In, M. Critchley, J.L. O'Learly, B. Jennet(eds.) *Scientific Foundations of Neurology*. London: Heinemann.

Wang, D.J.J., Jann, K., Fan, C., Qiao, Y., Zang Y-F, Lu, H. & Yang Y. (2018) Neurophysiological basis of multi-scale entropy of brain complexity and its relationship with functional connectivity. Frontiers in Neuroscience 12, 352.

Winters, J.J. (2020) The temporally-integrated causality landscape: a theoretical framework for consciousness and meaning. *Consciousness & Cognition* **83**, 102976.

Zamora-López, G., Chen, Y., Deco, G., Kringelbach, M.L & Zhou, C. (2016) Functional complexity emerging from anatomical constraints in the brain: the significance of network modularity and rich-clubs. *Scientific Reports* **6**, 38424.