The mechanism of phenomenal experience

A Reconstructive Systems Theory of Consciousness

Abstract

The essay develops a reconstructive systems theory of consciousness based on the causal self-closure of biological systems. Consciousness is not understood as a property or effect, but as the epistemic form that inevitably arises when the causal structure of a system is completely self-contained.

Physical, biological and phenomenal descriptions are epistemically autonomous forms of reconstruction that are structurally irreducible to each other. There is no translation relation between them, because they represent structurally heterogeneous modes of cognition within a single ontological basis.

In contrast to functionalist theories, which presuppose consciousness by definition, this model reconstructs consciousness genealogically: from thermodynamic self-organization to biological autocatalysis to neuronal oscillation dynamics. The central thesis is that consciousness is not an emergent property of complex systems, but the epistemic form that a physical system necessarily assumes when its causal structure collapses completely into itself.

For philosophers, this work shows why the hard problem is a category error: Physical and phenomenal description are different epistemic ways of reconstructing the same structure, not ontologically separated domains.

For neuroscientists, it combines measurable correlates (oscillation dynamics, perturbational complexity index) with the necessity of subjective experience and explains why global integration implies an internal perspective.

Keywords:

Causal Collapse, Autocatalytic Systems, Epistemic Self-Reference, Causal Core, Phenomenal Unity, Constructivist Epistemology, Hard Problem, Autopoiesis

1. The Categorical Position: System-Theoretical Reconstructivism

This position must be clearly distinguished from other theories of consciousness: Physical, biological and phenomenal descriptions are structurally autonomous epistemic reconstructions within an ontology that are neither in reduction nor in representational relation to each other.

The relationship between the epistemics can be illustrated by a concrete situation: a test subject solves a task, while a psychologist observes his behavior and a neuroscientist measures his brain activity. All three describe the same situation with categorically different epistemic grammar:

Psychological epistemics describes intentionality, the course of time, and actions. Physical epistemics describes causality, frequencies, spatial patterns. Phenomenal epistemics describes self-certainty, qualia, immediacy.

These three descriptions correlate (they refer to the same process), but they do not translate into each other. The terms belong to various epistemic grammars. What correlates is not the content, but the structure: autocatalytic self-organization manifests itself as goal-directed behavior (psychological), recursive network dynamics (physical) and self-affective experience (phenomenal).

The distinction between ontology and epistemics is itself epistemically mediated, there is no cognition-independent access to reality (Maturana & Varela, 1980; von Foerster, 1984). When we speak of an ontology, we mean the invariant structure of autocatalytic self-organization, which manifests itself in various epistemic reconstructions.

Key terms:

Causal collapse: The structural threshold at which the factorizability of causality is lost. This is not a dissolution, but integration to maximum unity (Stegemann, 2025a, 2025c).

Epistemic core: The necessary inner perspective that arises when a system completely maps its own dynamics within itself. It is not chronologically after the causal nucleus, but its intrinsic epistemic form (Stegemann, 2025e).

Autocatalytic closedness: A system that sustains itself through internal feedbacks (Kauffman, 1993). The products of its processes have an effect on their own causes.

Factorizability: The epistemic prerequisite that causes, effects, and states are distinguishable from each other. In consciousness, this prerequisite collapses.

Instantaneous self-reference: The complete feedback of a system to itself within a time window (~100 ms) that is shorter than the dissociation time of its processes.

2. The reconstructive method

The method used here is a reconstruction of the structural conditions under which consciousness arises. The concept of inevitability is central here because it expresses a clear causal relation: If these conditions are met, consciousness must arise.

A distinction must be made between evolutionary contingency and structural necessity:

Evolutionary Contingency: The Path to the Structure of Consciousness

The evolutionary path was not inevitable. Evolution could also have produced other solutions: Plants developed complex reaction systems without a nervous system, and many successful organisms remained single-celled. The laws of thermodynamics allowed the emergence of neuronal centralization, but did not force it.

Structural Necessity: From Structure to Consciousness

The inevitability does not lie in the evolutionary path, but in the structure-consciousness relation itself. It arises on two levels:

First: Thermodynamic necessity of causal centralization

Living systems are thermodynamically open, but operationally closed. This operational coherence forces a specific form of organization: energy flows circulate internally in such a way that the system stabilizes itself without dissipating (Prigogine, 1980). Wherever a system fulfills these conditions, a centralization of causality inevitably results: the causal core as a zone of maximum autocatalytic feedback.

This centralization is structurally enforced: a system can only survive where energy flows stabilize each other. In biological evolution, this principle manifests itself first in the cell nucleus (Lane & Martin, 2010), and later in the centralization of neuronal structures. The nerve pathways converge into integrative centers because the same thermodynamic logic that already gave rise to the eukaryotic cell nucleus finds its morphological continuation at a higher level.

Second: Logical necessity of epistemic transformation

Already at the level of autocatalytic closure, the principle of inseparability from causality arises. Where internal feedbacks are self-dependent, the separation of cause and effect loses its validity. This structure is initially realized purely physically-thermodynamically, but already has the logical form of maximum self-reference.

In the neuronal stage, this structure undergoes a qualitative transformation: electrical signal transduction accelerates feedback on time scales below 100 milliseconds (Buzsáki, 2006), making feedback instantaneous and oscillatory coherence integrating locally distributed processes into a global field. When these physical conditions are met, the factorizability of causality collapses completely. At this point, an internal perspective necessarily emerges, not as an additional property, but as the epistemic form that a system must take on when it refers to itself completely.

3. The factorizability of causality

A cause can only be determined if it can be distinguished from its effects and from other causes. This separability is an epistemic condition. It makes it possible to model systems, isolate processes and describe interdependencies.

As long as a system can be factorized in this way, the world remains analyzable. But in highly complex, recursive systems, this prerequisite becomes fragile. If feedbacks cause every change to react back to the conditions from which it itself emerges, then causality loses its directed structure.

Empirical science thrives on factorization. It has to disassemble systems in order to be able to examine them. But it has a price: what can be captured by factorization is never the whole, but always only one aspect. Philosophy begins where this methodological decomposition reaches its limits. Consciousness is precisely this state that eludes separation.

4. The logical collapse

In classical logic, statements can be evaluated independently of each other; in self-referential systems, every statement is part of a closed context. This means that the truth of a statement depends on the totality of the relationships in which it stands.

If this state is formally described, the result is a convergence structure that can be interpreted as a logical collapse. Each proposition is conditioned by other propositions, and these in turn are conditioned by those. The relation loses its asymmetrical direction. A symmetrical field of references emerges in which no statement exists in isolation.

In the meta-perspective, this can be understood as an epistemic borderline state. The classical logic, which presupposes difference and exclusion, collapses into a logic of self-identity. This collapse creates a new order: a system that refers to itself and thus forms a closed whole.

The term causal collapse refers to a structural threshold, not a temporal event (Stegemann, 2025a). What collapses is the factorizability of the causal structure, i.e. the possibility of analyzing causes and effects in isolation from each other.

How does the collapse take place? Increasing recursive feedback creates a state in which each variable depends on all others (Kelso, 2012), independent causal factors no longer exist, and the causal relation becomes symmetric.

What emerges: An indivisible causal wholeness, a system whose state can only be described as a whole, because every partial decomposition destroys the functional unity.

In this context, the term collapse does not refer to dissolution, but to a transition: the loss of factorizability. Causality is not destroyed here, but integrated into itself. Collapse is therefore a process of self-coherence in which cause and effect can no longer be separated.

5. The epistemic core

The self-reference of a system is the consequence of energetic self-organization, which is only possible in biological, autocatalytically closed systems (Kauffman, 1993). Chemical reaction systems can form dissipative patterns, but they have no functional boundary within which feedback stabilizes itself.

The decisive transition takes place as soon as a physical barrier is created that separates internal and external flows, but selectively couples them. In biological evolution, this is the cell membrane (Maturana & Varela, 1980). It creates a partial seclusion within which energy flows can mutually condition each other without dissipating. This membrane allows the products of a process to react back to its causes. This creates an inner, recursive flow equilibrium that is thermodynamically open but systemically closed.

In this equilibrium, the causal core is formed (Stegemann, 2025e). It is not an anatomical place or substance, but a dynamic zone of maximum self-reference in which internal energy flows regulate each other. This stability is not a functional structure, but a direct consequence of thermodynamic necessity: only systems that compensate for their dissipation internally survive (Prigogine, 1980).

The first form of this mechanism occurred in prokaryotic cells (Lane & Martin, 2010). Proton pumps, membrane potentials and enzymatic cycles formed closed energetic loops, the output of which was also an input. This created the kind of feedback that characterizes life: the ability to use one's own imbalance as a source of stability.

Where internal flows compensate for each other in such a way that they exist as a whole, a physical inside-outside difference arises, which later becomes the logical foundation of experience. The epistemic core of consciousness is thus the logical continuation of the causal core of biological autocatalysis.

Causal and epistemic nucleus are two descriptions of the same structure. The causal nucleus denotes the physical organization: the zone of maximum autocatalytic feedback. The epistemic nucleus denotes the same structure from its intrinsic perspective: the point at which self-reference becomes so complete that an inside perspective becomes logically necessary.

There is no temporal or causal transition between the two. They are epistemically autonomous reconstructions of the same autocatalytic organization.

6. The transition from chemical to electrical self-coherence

In the nervous system, the principle of self-coherence is accelerated and refined. Chemical gradients are replaced by electrical ones, and slow molecular reactions turn into oscillatory processes. Each nerve cell is an oscillator that oscillates in dependence on other oscillators (Buzsáki, 2006).

Neuronal oscillations do not form a linear signal chain, but a recursive network whose rhythmic patterns form a temporal structure that enables complex information processing (Buzsáki & Watson, 2012; Canolty & Knight, 2023). This autocatalytic excitability is already evident in the spontaneous activity of the brain: Even at rest, the default mode network generates continuous, self-organized patterns (Raichle, 2015).

Why neurons? The Contingent Necessity of Electrochemical Organization

The binding of consciousness to neuronal systems is functionally necessary, but not in principle exclusive.

Functional requirements for maximum self-reference: Feedback must be faster than dissipation processes (less than 100 ms), local activity must be globally integrable (over 10^9 elements), couplings must be adaptively modulable, and self-organization must be thermodynamically stable.

Neurons meet these requirements through electrical signal transduction (millisecond velocity), dendritic architecture (10^4 connections per neuron), synaptic plasticity, and membrane potential (energetic self-stabilization).

Is only electrochemical life capable of consciousness? Theoretically, no: any physical medium that meets the functional requirements could realize the causal collapse. In practice, only neural systems have so far fulfilled all of the above conditions simultaneously. Electrochemistry is not constitutive of consciousness, but the only known physical realizer of the necessary feedback dynamics.

Only the interplay of these properties allows the formation of a dynamic interior in which activity is constantly projected back onto itself. The electrical feedback occurs instantaneously within the biological time window of ~100 ms, so that there is no longer a temporal separation between cause and effect. Neural oscillations form a recursive network in which each element is modulated by all the others (Buzsáki, 2006).

Measurements show that conscious states are characterized by phase-dependent oscillations that synchronize wide-ranging areas (Engel & Singer, 2001; Fries, 2015; Melloni et al., 2007). EEG studies show that it is precisely this large-scale feedback that is retained in consciousness while it breaks down under anesthesia, deep sleep, or coma (Casali et al., 2013; Massimini et al., 2005; Demertzi et al., 2022).

The thalamus as a resonance organ

The thalamus acts as a resonance organ that couples distributed cortical processes in real time and thus stabilizes the inseparable dynamics of consciousness. Thalamo-cortical and cortico-cortical loops form recursive pathways through which electrical activity refers cyclically.

The electrical feedback of the brain is thus the physical realization of the logical principle of self-reference. Recent work on neural field theories (Pockett, 2000, 2012, 2023; McFadden, 2020) suggest that consciousness lies less in the spike pattern of individual neurons than in large-scale electric field dynamics.

Thus, the electrical modality is not accidental, but constitutive: it is the only one that enables the autocatalytic feedback, the oscillatory dynamics and the self-affection that together form the phenomenal interior of consciousness.

7. Empirical Implications

The model provides testable hypotheses. If consciousness is the consequence of maximum self-reference, then any disruption of this coherence should lead to loss of consciousness. EEG studies show exactly that: In anesthetized or comatose states, the globally effective oscillation dynamics decrease (Massimini et al., 2005; Comolatti et al., 2023). Conversely, large-scale synchronicity increases in states of focused attention (Northoff et al., 2021).

The causal core of human consciousness can be characterized from three complementary perspectives:

From an anatomical and functional point of view, the causal nucleus lies in the thalamocortical system. Here, sensory and motor information from the entire organism converge, are processed recursively and kept temporally coherent by fast electrical signal transmission. The massive reciprocal connectivity between the thalamus and the cortex creates a range of maximum causal density where cause and effect are no longer separable.

Process-oriented , the causal nucleus is not a fixed anatomical structure, but a dynamic configuration: it arises where thalamocortical loops achieve sufficient density, recursiveness, and temporal coherence (Deco & Kringelbach, 2020). This configuration is typically realized in the waking state and collapses under anesthesia or in deep sleep (Alkire et al., 2008), exactly when thalamocortical communication is interrupted.

Causally-structurally , the causal nucleus refers to that totality of neuronal processes that can no longer be factored into independent sub-processes due to recursive entanglement and central position. In the human brain, the thalamocortical system is the primary carrier of this structure.

Empirical validation:

Necessity: Disturbances in thalamocortical loops lead to loss of consciousness. Thalamic strokes can lead to coma despite preserved cortical function (Schiff, 2010). Anesthetics specifically interrupt thalamocortical communication (Alkire et al., 2008). Deep brain stimulation in the intralaminar thalamic nucleus can activate patients from the minimally conscious state (Schiff et al., 2007).

Sufficient complexity: The system must have a minimum size and specific connectivity. The cerebellum has more neurons than the cortex, but it does not contribute to conscious experience because it lacks the central, recursive architecture (Tononi & Koch, 2015).

Temporal coherence: Oscillatory synchronization, especially in the gamma band, correlates with conscious processing (Fries, 2015; Melloni et al., 2007). This synchronization keeps the entangled processes together within the critical time window of ~100 ms.

Causal Non-Factorizability: The Perturbational Complexity Index (PCI) measures how complex a system responds to local perturbations with global, non-factorizable patterns (Casali et al., 2013). High PCI values correlate with consciousness, low ones with unconsciousness.

8. The inevitability of consciousness

The central thesis of this model is that as soon as a system achieves complete causal self-reference, an epistemic form necessarily arises, which we call consciousness. This necessity is neither empirical nor causal, but categorical: it follows from the structure of self-reference itself.

External description presupposes the possibility of separating causes from effects. If this separation is lost through complete feedback, only an intrinsic perspective remains. This is not added, but the logical form of maximum integration.

Therefore, consciousness is not an emergent property, but the epistemic form of complete self-reference. Where a system refers to itself completely, it can only be grasped from within, and this from within is consciousness.

A system that maps its own dynamics completely recursively creates a closed loop. Each of its state changes not only affects other states, but also itself. This represents the dynamic presence of consciousness. It is the state in which a system experiences itself as continuously identical, although it is constantly changing. The subjective experience of the now, continuity, and self-identity is the phenomenal manifestation of this recursive stability.

This form of self-coherence is tied to biological organization. Only systems that have a functional limit can maintain such recursive stability. Consciousness is therefore not a universal feature of matter, but a specific expression of biological autonomy.

The Causal Core as a Reference Zone of Functional Density

In recursively closed systems, the causal core forms the zone of maximum self-reference. In it, the central feedback loops meet and stabilize a dynamic center that is neither spatial nor substantial, but a form of maximum functional densification. This condensation creates an internal gradient in the system, as not all areas are equally integrated into the recursive integration structure.

The causal nucleus acts as an internal reference point, on the basis of which these differences appear as differences in the first place. Externally, the system appears homogeneous as a network of interacting processes. Internally, however, the densification zone of the core creates a relative order in which states are closer or farther away, more relevant or more irrelevant, more stable or more unstable.

This internal differentiation is the decisive step towards an internal perspective. A system that completely passes through its own state space and thereby creates inseparable transitions can only grasp these transitions relative to its core. Phenomenal experience therefore arises not as an additional property, but as the epistemic form that becomes necessary when a system can only grasp differences relative to its own center.

This structure also explains the temporal commitment of conscious content. The causal nucleus forms its coherent reference point only within the time window in which all relevant loops are simultaneously integrated. Biologically, this integration width is in the range of about one hundred milliseconds.

The causal core is not an inner observer

The description of the causal core could give the impression that an entity is emerging at the center of the system that observes the rest of the process. However, such an idea would be a category error. The nucleus is not an entity or an inner subject, but the dynamic form that a system takes on as soon as its recursive feedbacks reach maximum density.

This structure precisely excludes the possibility of an inner observer. A homunculus presupposes an internal separation, a difference between an observing center and a process under consideration. The causal nucleus makes such a difference impossible because it is the condition under which all states integrate into a single feedback context.

The internal perspective therefore does not arise in the core and is not transferred by him. It is the epistemic form of the structure in which the nucleus is the only possible reference. The nucleus eliminates the homunculus because it describes a structure that does not allow for any internal entity that could control or observe the entire process.

9. The hard problem as a categorical confusion

The hard problem formulated by David Chalmers asks: Why and how do phenomenal qualities of experience emerge from physical processes? This question is categorically wrong because it presupposes three untenable assumptions: an ontological priority (physical processes are more fundamental), a causal derivation (there must be a mechanism that turns physics into consciousness), and an aspect duality (there are two sides that would have to correspond).

The solution: The problem disappears because the question commits a category error. Neuronal coherence is the physically-causally reconstructed form of maximum self-reference; Consciousness is the reflexive-epistemically reconstructed form. There is no derivation because there is no ontological difference that would have to be bridged.

Analogy: The question of how gravity arises from the curvature of space-time is wrong, because curvature is gravity, only in geometric instead of force language. In the same way, there is no transformation from physics to consciousness.

The hard problem is not an empirical problem that can be solved, but a philosophical error that arises from the confusion of epistemic plurality with ontological duality.

10. Differentiation from other theories

Most contemporary theories of consciousness describe neuronal correlates without explaining why these correlates constitute phenomenal experience. They label consciousness instead of reconstructing it. This methodological weakness is particularly evident in three influential approaches:

Integrated Information Theory (IIT): IIT quantifies integration by the value Φ (Tononi et al., 2016) and postulates that every system with $\Phi > 0$ is conscious. This leads to absurd consequences: simple circuits or thermostats could have high Φ values and would therefore be conscious (Aaronson, 2014). IIT measures a property and declares it to be the cause of consciousness, without justifying why integration should produce experience at all. This is not an explanation, but a label: integration becomes the name for consciousness, not its genealogy. IIT presupposes what it should explain.

Global Workspace Theory (GWT): GWT describes that deliberate content is made available globally (Dehaene & Changeux, 2011). But why does global availability create subjective experience? A computer network also makes information globally available without being conscious. GWT describes a functional mechanism (broadcasting), but labels it as consciousness, without explaining the categorical transformation of information into experience. Theory says what is processed, not how it is experienced.

Predictive Processing (PP): PP models the brain as a prediction machine that minimizes errors (Clark, 2013; Hohwy, 2013). But error minimization is an optimization strategy that occurs in every technical system. Why should it suddenly generate consciousness in biological systems? PP describes functional mechanisms and labels their integration as consciousness, without explaining why these mechanisms imply an internal perspective.

The common flaw of these theories lies in their method: they identify neuronal properties (integration, broadcasting, error minimization), observe their correlation with consciousness, and then declare these properties to be constitutive features. This is circular. They answer the question 'What correlates with consciousness?' instead of 'Why does an inner perspective necessarily arise?'

In contrast, this model reconstructs the structural conditions under which an internal perspective must inevitably arise: thermodynamic self-organization forces autocatalytic closure, which forces causal centralization, and when this centralization becomes instantaneous through electrical feedback, the factorizability of causality collapses. At this structural threshold, an epistemic form necessarily emerges that is accessible only from within.

11. Recognition as an autocatalytic process

Consciousness is not the end product of a gradual process, but a categorical transition. Where self-reference is maximized, an internal perspective necessarily emerges, not as a causal consequence, but as an epistemic implication of the structure. This transition is a threshold phenomenon: either causality can be factorized or it collapses. Consciousness is thus the epistemic form that logically follows from maximum self-reference.

If consciousness is the epistemic form of being, then the world as it appears to us is also an epistemic construction (von Foerster, 1984). Every physical theory does not describe being per se, but relationships within an observer structure. Knowledge is the ongoing stabilization of an autocatalytic system that produces its own world.

In concrete terms, this means that stimuli are part of the autocatalytic process when they arrive in the brain, without which the brain would not be able to survive.

Inference

Consciousness is neither a metaphysical enigma nor a mere effect of biological complexity. It is the necessary epistemic form of autocatalytic self-organization as soon as it crosses a structural threshold. While autocatalytic closure occurs even in the simplest living systems, conscious states only arise where this dynamic meets specific physical conditions: electrical signal transduction, oscillatory dynamics and time scales below 100 milliseconds.

When the internal feedback of a system becomes so dense that its causal relationships can no longer be factorized, a categorical transition takes place: the system loses the possibility of external description and must necessarily have an internal perspective. On the physical level, this appears as an autocatalytic state of stability, in epistemic reconstruction as experience.

This position can be summarized in four theses: First, non-reductivity, because consciousness cannot be derived from physical descriptions. Second, non-duality, because consciousness is not an additional substance, but an epistemically autonomous reconstruction. Thirdly, structural necessity: as soon as a system fulfils the physical conditions, it must have an internal perspective, as a logical implication of its structure (Stegemann, 2025b). Fourthly, biological contingency, because these conditions have so far only been realised in neuronal systems.

The brain is not a place of consciousness, but its morphological condition, a dynamic resonating body in which energy flows create a closed epistemic space.

It is time to say goodbye to representationalist and obektivist theories, both in the philosophy of mind and in epistemology.

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