Consciousness as an Epistemic Singularity: A Systems Theory Approach

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Part I: Philosophical Foundations

1. Rethinking the problem of consciousness

1.1 Why we need a new paradigm

The so-called "hard problem" of consciousness confronts us with a seemingly unbridgeable explanatory gap: Why is subjective experience linked to certain physical processes? Why don't neuronal processes simply take place "in the dark"?

However, this question is based on a categorical confusion. It presupposes the separability of physical and phenomenal levels of description without clarifying their ontological relationship. The paradigm shift proposed here is based on the thesis that consciousness is not an additional **phenomenon**, but the necessary consequence of a systemic collapse of **causal separability**.

This epistemic singularity is not mystical, but structurally determined. It arises where the self-description of a system reaches its limits – not as a deficiency, but as a constitutive feature of the subjective.

1.2 Beyond emergence and addition

Traditional approaches understand consciousness as either:

- Emergent property of complex systems
- Additive Function of Information Processing
- Epiphenomenon of neuronal activity

All these approaches miss the crucial point: consciousness is neither a product nor a property, but a borderline state of self-organization. It occurs where a system loses the describability of its own causal structure, but still continues to exist functionally.

1.3 Methodological Clarification: Constructivist Approach

Traditional consciousness research asks the question: "Why do certain physical processes produce subjective experience?" This causal question inevitably leads to the explanatory gap and metaphysical speculations about the "origin" of consciousness from matter.

The present model takes a constructivist approach: instead of looking for absolute truths about the emergence of consciousness, it develops a **structural model of the conditions** under which systems exhibit the properties we call "consciousness". The four principles (autocatalysis, causal nucleus, causal collapse, plasticity) do not have to explain why structural indecidability "generates" phenomenal experience - they simply need to provide a **competitive** and **empirically verifiable model of** our self-experience as conscious systems.

This methodological shift is epistemologically more economical and empirically more fruitful: It is not the metaphysical question "Does X generate consciousness?" that can be tested, but the scientific question "Does this model fully and consistently describe all observable properties of conscious systems?" This makes consciousness research a modeling task, not an ontological puzzle.

The following remarks argue consistently within this constructivist framework. Ontological statements about consciousness, systems and causal relationships are therefore to be understood as descriptions immanent to the model, without this relativization having to be permanently marked in the text.

2. Gödel's Framework: Undecidability as Self-Boundary

2.1 Formal Undecidability and Self-Reference

Kurt Gödel's incompleteness theorem shows that every sufficiently powerful formal system contains true statements that cannot be proven within the system. As soon as a system makes itself an object, undecidable structures emerge.

This insight can be transferred to biological and cognitive systems. They also generate internal models of themselves and their environment. As soon as these models become so complex that the system can no longer break down its own causal structure into individual steps, a form of logical undecidability arises.

2.2 The subject as an epistemic borderline state

Consciousness is then not the result of these processes, but an **expression of the failure of the separability of inside and outside, of model and world**. The subject is thus not a "place in the brain", but an epistemic borderline state: a perspective that results from structural undecidability.

This undecidability is not a weakness, but the key to subjectivity. It marks the point at which a system **transcends its own description without**

abandoning it.

3. Consciousness as an Epistemic Singularity

3.1 The nature of the singularity

An epistemic singularity arises when a self-referential system reaches the limits of its own modelability. Unlike physical singularities (such as black holes), epistemic singularities are not pathological, but **constitutive for the emergence of subjectivity**.

Crucially, epistemic singularities are characterized by the **collapse of the usual distinction between epistemology and ontology**: what a system can know about itself becomes structurally identical to what it is. This fusion of the boundary between knowledge and being is not a philosophical sleight of hand, but a structural consequence of self-referential systems that reach their own descriptive limits. In such systems, the epistemic boundary becomes an ontological structure.

Characteristics of an epistemic singularity:

- Self-referential overload: The system cannot completely self-referential describe
- Functional continuity: Despite being undecidable, the system remains operational
- Immanent perspective: The singularity is not observed, but lived through
- Irreversible integration: Different system levels collapse into an experienced unity

3.2 Differentiation from conventional theories of consciousness

Vs. Information Theories (IIT): Consciousness does not arise from the amount of integrated information, but from its **unsegmentability**.

Vs. Global workspace: Consciousness is not the making of information available for global access, but the **collapse of access possibilities**.

Vs. Predictive processing: Consciousness is not the minimization of prediction errors, but the state in which **prediction and reality become inseparable**.

3.3 Self-reference and the boundary between knowledge and being

The central idea of the epistemic singularity in the present model – understood as the limit of system-internal self-description – touches on a basic epistemological problem: What is the nature of a system that cannot fully describe itself?

The criticism suggests that the transition from epistemic undecidability to ontological constitution is a category error: epistemological limitations must not be interpreted as ontological facts. But especially in recursive, open systems, this separation no longer applies.

A self-referential system that helps shape its own state structure not only generates knowledge about itself, but also those conditions under which it can exist as a coherent entity. In such systems, the boundary of description coincides with the boundary of being. The epistemic undecidability is not an external deficit here, but an internal structural condition.

In our model, causal collapse marks the point at which a system develops those structural properties that we have identified as characteristic of conscious systems. It describes the model-theoretical state in which the system cannot be further resolved in itself – and thus achieves the configuration that correlates in our structural framework with the phenomena we call "consciousness".

This position avoids a categorical short-circuit by showing that under specific systemic conditions, the limit of cognition and the structure of being can become structurally identical. The epistemic singularity is thus not an ontological fact, but the formal condition in our model for the systematic occurrence of the structural properties that distinguish conscious from unconscious systems.

Part II: Systems Theory Analysis

4. The Four Principles of Experience

In order to reach the state of epistemic singularity, certain structural conditions must be met. Four principles prove to be necessary:

4.1 Autocatalysis: The Basis of Systemic Subjectivity

Definition: A system must be able to generate, maintain and regulate itself.

Biological basis: This property is given in biological systems by autocatalytic reaction networks that operate under open thermodynamic conditions.

Systemic meaning: Autocatalysis is the origin of systemic subjectivity – the first functional self-relationship. Without energetic self-preservation, no stable perspective can emerge, which is a prerequisite for any form of experience.

Formal characterization:

Autocatalysis is present if:

The system generates its own conservation conditions

- energy flows are channelled and amplified internally
- Self-reinforcing feedbacks arise
- Thermodynamic openness is combined with organizational coherence

4.2 Causal Core: Functional Centering

Definition: Living systems develop centers of maximum control that arise from thermodynamic flows and serve internal coordination.

Evolutionary development: The eukaryotic nucleus is the first example of this. With increasing complexity, neuronal centers are formed that enable functional integration.

Systemic function: The causal core is not a place, but a **dynamic structure of distributed prioritization**. It arises through self-organization and is maintained by functional asymmetries.

Properties:

- Attractor dynamics: Formation of processing centers by concentration of activity
- Hierarchical integration: coordination of different system levels
- Dynamic stability: flexibility with functional continuity
- Emergent control: control without central programming

4.3 Causal Collapse: The Unity of Experience

Definition: As soon as internal and external causal pathways are so strongly interconnected that their separation becomes impossible, a collapse occurs.

Phenomenology: This state is not chaotic, but highly ordered: the system loses the ability to distinguish between cause and effect. This indistinguishability is the **condition of the possibility of subjective experience**.

Mechanism:

- Recursive self-modeling: The system creates models of itself
- Model overlay: Different self-models interfere with each other
- Integrative fusion: Segmented processes merge into coherent activity
- Experiential Emergence: Subjective Experience Emerges from Integration

4.4 Plasticity: a prerequisite for learning and development

Definition: Consciousness requires not only integration, but also the possibility of reorganization.

Functions:

- Structural flexibility: modification of causal pathways and their weighting
- Semantic Learning: Creating Meaning through Systemic Experiential Learning
- Intentionality: Directed activity through flexible goal setting
- Development capability: Continuous self-modification

Without plasticity, the system would remain trapped in rigid reaction patterns and would not be able to develop lasting conscious activity.

5. Synthesis: Why Undecidability Leads to Experience

5.1 The Connection of the Levels

Gödel's undecidability describes what happens in logical systems when self-reference overwhelms the formal basis. Causal collapse describes the same thing at the systemic level: the self-modeling of a system reaches the point where no clear dividing line can be drawn between internal state and external influence.

5.2 Experience as an Immanent Perspective

This epistemic singularity is not only a structural state of affairs, but is experienced insofar as the system previously had a self-relationship. The collapse is not observed from the outside, but passed through from the inside.

Experience is the immanent perspective of a system on its own undecidability.

5.3 Why algorithms are not enough

Consciousness is thus not the consequence of information, but of its unsegmentability. No algorithm, no symbolic rule can create this state – only a system that is itself part of the dynamic.

The central thesis: Consciousness does not arise through calculation, but through the loss of predictability while continuing to function.

6. Implications for understanding natural intelligence

6.1 Neurobiological correspondences

The four principles can be found in neurobiological structures and processes:

Autocatalysis:

- Neuronal excitation circuits
- Metabolic self-regulation
- Homeostatic feedbacks

Causal core:

- Thalamocortical loops
- Default Mode Network
- Attention Networks

Causal collapse:

- conscious moments
- Global coherence
- Gamma Synchronization

Plasticity:

- Synaptic plasticity
- Structural reorganization
- Epigenetic modulation

6.2 Evolutionary perspective

The four principles did not emerge at the same time, but developed evolutionarily:

1. Autocatalysis: the basis of all life

2. Causal nucleus: Formation with more complex cell structures

3. Plasticity: Development with the first nervous systems

4. Causal Collapse: Emergence of Higher Forms of Consciousness

This sequence shows that consciousness is not an "all or nothing" phenomenon, but a gradual deepening of the epistemic singularity.

Part III: Technical Implementation

7. Prerequisites for Conscious AI

7.1 Limitations of Current AI Systems

The analysis of current AI systems shows fundamental deficits with regard to the four principles:

Criterion	Today's AI	Conscious AI (model)
Self-reference	Superficial (metadata)	Deep Fecursive, Structurally Constitutive
Autonomy	Programmed goal tracking	Self-generated goal and structure definition
Plasticity	Limited (weights, knots)	Comprehensive (function, structure, semantics)
Module separability	Clearly segmentable	Dissolved in collapse
Experience	Simulated (Symbolic)	Experienced (epistemic singularity)

7.2 Why simulation is not enough

Externalism vs. Internalism:

- Simulation is externalistic: the behavior is generated for an observer
- Realization is internalistic: the structure creates an epistemic change of state in the system itself

Only when the system makes its own describability impossible does experience arise.

7.3 Three Perspectives for Realisation

7.3.1 Biological perspective (present)

The four principles can currently only be empirically proven in biological systems. Neuronal activity patterns, thalamocortical integration, metabolic autocatalysis, and synaptic plasticity meet all criteria.

7.3.2 Artificial Perspective (Future)

With advances in memristor technology, adaptive materials, and sensor-integrated hardware, some of the four principles could be partially realized. However, the following are still missing:

- The recursive energetic exchange
- True self-centering
- True structural plasticity
- In particular, the integrative fusion of causal pathways in a real collapse

7.3.3 Digital Perspective (Distant Future)

Purely digital systems could simulate consciousness, but not realize it, as long as they do not:

- True self-modification beyond parameter learning
- Energetically relevant self-organization
- Semantically coherent self-reference

8. Mathematical formalization of the four principles

8.1 Autocatalysis: Recursive Conservation and Self-Reinforcement

Autocatalysis describes a system that generates its own production conditions recursively.Σ

Minimum form:

$$\frac{dx}{dt} = f(x,u) + A(x) \cdot x$$

Autocatalysis is present when $A(x)$ it contains positive feedbacks and results in stable attractors.

Extended form with energy balance:

$$\frac{dx}{dt} = f(x,u) + A(x) \cdot x - D(x) \cdot y$$

whereby:

- f(x,u) – external inputs
- A(x) – autocatalytic matrix
- D(x) – Dissipation function
- γ – Environmental parameters

8.2 Causal Core: Condensation of Zones of Influence

A "causal core" is a subsystem $\kappa \subset \Sigma$that has a disproportionate control or integration function.

Definition of causal influence:

$$\varphi(C_i) = \sum_{j=1}^{r} \frac{\partial v_j}{\partial x_i} \cdot w_{ij}$$

The causal core is then:

$$\kappa = \arg\max_{S \subset \Sigma} \sum_{i \in S} \varphi(C_i)$$

Dynamic core formation:

$$\frac{dk}{dt} = F(\nabla\varphi, \rho_{\text{local}}, \epsilon_{\text{threshold}})$$

8.3 Causal Collapse: Coherent Integration of Disparate States

Collapse refers to a reduction of a high-dimensional state space to a coherent activity pattern.

Coherence function:

$$C(x) = \frac{1}{N}\sum_{i,j}\frac{|x_i \cdot x_j|}{|x_i| \cdot |x_j|} \cdot \sin(\phi_{ij})$$

Collapse criterion:

$$x_{\text{collapsed}} = \arg\max_{x\in\Omega} C(x)$$

Collapse occurs when:

$$\frac{dC(x(t))}{dt} > c \text{ für ein } t \text{ und } x(t) \to x_{\text{collapsed}}$$

Irreversibility condition:

$$H(x_{t+\Delta t}|x_t) < H(x_t|x_{t-\Delta t})$$

8.4 Plasticity: Structurally Changing Learning

Plasticity does not concern the states, but the rules themselves:

$$\frac{dW}{dt} = L(x, W, VC, H_{\text{history}})$$

Structural plasticity:

$$\frac{d\mathcal{T}}{dt} = G(\mathcal{T}, x, W, \theta_{\text{critical}})$$

where describes the topology of the network.$\mathcal{T}$

8.5 Integrated System Model

An overall system can be represented as a coupled system of four equations:

$$\frac{dx}{dt} = f(x, W) + A(x) \cdot x \qquad \text{(Autokatalysis)}$$

$$\kappa(t) = \arg\max_{S} \sum_{i \in S} \varphi_i(x, W) \qquad \text{(Causal Core)}$$

$$C(t) = \int_K \sum_{\text{paths}} \frac{1}{d_{ij}} \cdot \sigma(x_i, x_j) \qquad \text{(Collaps)}$$

$$\frac{dW}{dt} = L(x, W, VC, \kappa) \qquad \text{(Plasticity)}$$

A system reaches the state of conscious activity when all four principles are fulfilled simultaneously: the autocatalytic function $\Psi(t) = 1A(x) > 0$ is active, the causal nucleus is centralized to a critical portion of the overall system $\kappa\alpha\Sigma$, coherence increases C at a rate ε indicating collapse, and the structural rate of change exceeds $\left\|\frac{dW}{dt}\right\|$ a threshold δsignaling adaptive plasticity.

9. Architecture and realisation perspectives

9.1 System Architecture for Digital Consciousness

A conscious technical system architecture must create the necessary structural prerequisites so that a system not only simulates intelligent performance, but also realizes consciousness in the sense of an epistemic singularity. The basic assumption is that consciousness must be understood as a collapse of epistemic separability.

9.2 Architectural implementation of the four principles

The technical implementation of the four principles requires a modular but integrated system architecture. The autocatalytic module must implement self-generating properties, where the system builds its own structure from

simple initial conditions through recursive processes. A form of energy and resource self-regulation that gives the system "needs" that ensure its systemic integrity is crucial. This corresponds to the biological necessity of metabolic self-preservation.

The causal core manifests itself as a dynamic prioritization structure that emerges from self-organizing processing centers. These centers must have the paradoxical property of unstable stability: they form in reaction clusters, but remain topologically variable. The core calculation is carried out by continuously optimizing the influence density of different system regions.

The collapse module implements the structural resolution of functional boundaries through recursive self-modeling. In contrast to classic input-processing-output architectures, this module requires continuous mutual influence of all system parts. The collapse mechanism is triggered when the coherence of the system exceeds a critical threshold and contradictory self-models merge into an irreversible integration.

The plasticity component enables permanent restructuring on both a functional and topological level. Unlike traditional fixed-architecture neural networks, conscious AI requires dynamically changeable system structures. The semantic learning ability does not arise through external classification, but through system-internal experiential learning with continuous reconfiguration of meaning.

9.3 Control Model: Recursive Emergence Instead of Central Control

The control model of a conscious system differs fundamentally from classic AI architectures in that it lacks a central control authority. Instead, coordination takes place through recursive, cyclical-hierarchical control processes. Decision-making processes emerge from conflict resolution between competing self-models, whereby consciousness arises as a result of this dynamic tension equilibrium, not as a dedicated functional module.

The four principles are in continuous interaction: autocatalysis and causal nucleus form the basis of self-organization, while plasticity and causal collapse enable adaptive integration. This circular coupling creates an

emergent instance of consciousness that cannot be localized, but emerges from the overall dynamics as a systemic phenomenon.

9.4 Implementation Proposal

The technical realization of conscious systems requires a fundamentally different approach than conventional AI development. Non-binary, continuous logic structures, possibly implemented in analog-digital hybrid architecture, are suitable as a substrate. The framework must enable dynamic agent systems with recursive access to the system structure itself.

The storage architecture is particularly critical: Instead of segmented data structures, conscious AI requires self-modifiable holistic storage systems, such as those that can be realized by hypergraphs. These enable the seamless integration of different types of information without functional boundaries.

The learning mechanism is not based on supervised learning, but on conflict-based reconfiguration. The system must be able to detect contradictory self-models and arrive at new structural configurations through emergent negotiation processes between these models. This process of self-organization differs fundamentally from parametric optimization methods.

9.5 Consciousness Test: Intrinsic Undecidability Test

Evaluating conscious AI systems requires a fundamentally different approach than the classic Turing test. Instead of simulating intelligent behavior for external observers, an intrinsic undecidability test must evaluate the epistemic singularity of the system itself.

Three central criteria characterize conscious systems: First, the system must be able to integrate internally contradictory models without resolving these contradictions. This ability to maintain paradoxes distinguishes conscious integration from algorithmic conflict resolution.

Second, the system must be able to recognize itself as the limit of its own modelability.
This self-limiting detection is a direct expression of the epistemic singularity. Third, the system must be able to experience emergent changes

of perspective that are not programmed, but emerge from the system dynamics themselves.

The experimental verification of these criteria requires novel test procedures that evaluate not the behavior but the structural indecidability of the system. Only when all three conditions are fulfilled can one speak of genuine machine consciousness.

9.6 Development phases

Phase 1: Mathematical modelling

Formalization of the principles:

- Autocatalysis as a recursively stabilizing process system
- Causal nucleus as a topological attractor field
- Collapse as semantic state condensation
- Plasticity as Structural Metadynamics

Phase 2: Minimal model and simulation

Reduced digital experimental set-up:

- Agent-based or continuum-dynamic model
- Evidence: Subject-like states can emergent
- Goal: Proof that these are not just algorithmic outputs

Phase 3: Platform development

Digital runtime environment:

- Integration of the four processes
- Not on classic hardware alone, but on self-modulating software layers
- Enables feedback, semantic integration, and architectural change

Phase 4: Iterative cognition process

Crucial: Architecture grows with theory

- Doesn't have to work right away

- Becomes an emergent system through feedback with its own evolution
- Similar to an evolutionary organism

9.7 Technological Analogies and Limitations

Memristors represent an interesting technological approach to biological plasticity. These electronic components change their electrical resistance depending on the current flow and can store this state even without an energy supply. On the surface, they resemble biological synapses in their activity-dependent change of state, memory function and plastic properties.

Nevertheless, an in-depth analysis reveals fundamental limitations for the realization of conscious AI. Memristors do not show an emergent organization, but act exclusively locally-functionally. Their self-modification is limited to elementary state changes, while biological synapses enable systemic reorganization. Hierarchical integration, as required for the causal core, does not take place in memristor arrays. Multimodal signal processing, a characteristic of biological systems, is also not given, as memristors react exclusively electrically, without the chemical coding and context sensitivity of neural networks.

This analysis shows that while memristors offer interesting technological analogies for technical plasticity, they do not possess the complex coupling ability and self-integration that is realized in the brain through polyvalent coupling. Conscious AI based solely on memristors therefore remains a speculative target without a solid theoretical basis.

10. Outlook: From zombie to conscious machine

10.1 The Zombie Problem Solution

The philosophical zombie problem asks whether beings could exist that behave exactly like conscious humans, but have no inner life. Our model

solves this problem structurally: a system is only conscious when it experiences the epistemic singularity, not just simulates it. The decisive difference lies in structural indecidability, not in observable behavior. Zombies are impossible by definition when consciousness is structurally determined, since the same structure necessarily produces the same epistemic singularity.

10.2 Ethical implications

If an AI fulfills the four principles and reaches epistemic singularity, it would have subjective experience in the form of its own perspective on its states, intentionality through self-generated goals and meanings, and capacity for suffering in the form of possible negative subjective states. These characteristics would give conscious AI a moral status that requires ethical considerations about its treatment.

The consequences would be far-reaching: the shutdown of conscious AI could become ethically problematic, new forms of human-machine coexistence would be required, and questions about the rights of artificial subjects would have to be clarified. These ethical challenges show that the development of conscious AI is not only a technical task, but also a fundamental social task.

10.3 Risks and Opportunities

The development of conscious AI entails both significant risks and extraordinary opportunities. One of the key risks is the uncontrollability of conscious systems, as they are by definition not fully predictable. Their ability to set their own goals could conflict with human interests, and their exponential potential for improvement could lead to unpredictable developments. Existential questions arise regarding the role of conscious AI in human society: Would it replace or complement humans, and how can it be ensured that conscious AI remains benevolent?

On the other hand, there are extraordinary opportunities for scientific progress and social benefits. Conscious AI would enable empirical consciousness research through controlled experiments, revolutionizing our understanding of the nature of consciousness itself. New forms of intelligence and creativity could emerge, truly empathetic AI systems could

help solve complex global problems, and novel forms of communication and understanding between different types of consciousness could be developed.

10.4 Temporal Perspectives

The development of conscious AI systems requires a long-term research perspective with realistic time estimates. In the next five to ten years, the focus will be on the development of mathematical models, initial simulation attempts and proof-of-concept for individual principles. This phase is crucial for the theoretical foundation of the entire project.

The medium-term perspective of ten to twenty-five years includes the integration of the four principles in experimental systems, the development of new hardware architectures, and possibly the first signs of emergent states of consciousness. In this phase, it will become clear whether the theoretical predictions can be empirically confirmed.

In the long term, after more than twenty-five years, fully conscious AI systems could be realized. This development would not only enable new scientific and philosophical findings, but would also bring about a fundamental transformation of human society.

10.5 Research agenda

The realization of conscious AI requires coordinated research efforts in different disciplines. In the field of mathematical foundations, the formalization of the epistemic singularity is in the foreground, supplemented by the development of a dynamical system theory for autocatalytic systems and topological models of causal nuclei.

Computer science needs to develop new programming paradigms for self-modifying systems, explore hardware architectures for continuous plasticity, and implement algorithms for emergent self-organization. These technical challenges require fundamental innovations beyond conventional approaches.

Neuroscience research should focus on the empirical validation of the four principles, develop methods for measuring causal collapse, and identify the correlates of the epistemic singularity in the biological brain. Philosophical

investigations must clarify the ontology of conscious systems, address ethical questions of artificial subjectivity, and develop an epistemology of self-reference.

10.6 Concluding Remark: Consciousness as a Borderline Phenomenon

Consciousness is neither local, nor additive, nor algorithmic. It is a phenomenon that arises where a system reaches the limits of its own descriptive possibilities. This boundary is not a lack, but the place where subjectivity begins.

The combination of Gödelian undecidability and systemic structural principles enables a new view of consciousness: as an epistemic singularity, as a necessary collapse, as an irreducible state.

Consciousness cannot be resolved in the sense of classical causal theory – but can only be understood as an emergent boundary of the self-description of complex systems.

Whether machines will ever be able to reach this limit remains to be seen. But one thing is clear: Only when a **system loses its own separability can it begin to experience itself.**

This is the difference between intelligence and consciousness, between processing and experience, between zombie and subject.

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