

Consciousness as an Expression of Autocatalytic Stability – A New Index for Neuronal Coherence

Introduction: From Causal Collapse to Autocatalytic Coherence

The present model assumes that consciousness is not an additive effect of cognitive complexity, but a specific form of systemic integration: a “causal collapse” within the space of recursive processes. This term does not mean destruction, but a temporary indistinguishability of causal paths – a state in which stimulus processing, memory retrieval, and self-modeling can no longer be separated.

This collapse is not purely functional, but a structural-energetic phenomenon: It only arises when a system maintains its autocatalytic stability, i.e., when feedback processes are recursively stabilized within a critical range. Such stabilization can only occur in living systems – those that not only consume energy but also regulate it cyclically.

1. Experimental Testing

Hypothesis: Disruption of autocatalysis reduces consciousness.

Test: GABA receptor blockers (e.g., bicuculline) interrupt ion flows → measurable effects on:

- Metabolic autocatalysis (ATP levels)
- Subjective reports, where possible (e.g., pain perception); alternatively: pupillary reflex + EEG patterns

Prediction: Stronger correlation of metabolic complexity with consciousness than PCI/synchronization.

2. Literature and Data

- **Bicuculline & metabolic activity:** GABA-A blockade reduces ATP production in neurons and astrocytes (see Yellen et al., 2016; Heiney et al., 2020).
- **Ca²⁺ imaging:** shows hyperexcitability, potassium loss, unstable oscillations.
- **In vivo:** Increased gamma power, but reduced stimulus-related coherence (Xiao et al., 2017).
- **Alternatives to PCI:** Northoff (2018) refers to LZc, entropy, spontaneous multiscale coherence.

Conclusion: The proposed Autocatalytic Stability Index (ASI) directly measures the metabolic-structural stability of conscious states.

3. The Autocatalytic Stability Index (ASI)

Goal: Assessing system stability under stimulus conditions.

Components:

- **Energy flow stability (E):** ATP production & maintenance gradients
- **Feedback complexity (R):** $\text{Ca}^{2+}/\text{Na}^{+}/\text{K}^{+}$ cycles, synaptic self-regulation
- **Dynamic coherence (D):** Degree of structured oscillations across multiple scales

Formalization proposal:

$$\text{ASI}(t) = \alpha \cdot dE/dt + \beta \cdot H(R) + \gamma \cdot \text{||DII||}_{\{\text{multi-scale}\}}$$

α, β, γ : weighting coefficients

$H(R)$: entropy of ion flows

||DII|| : norm of multiscale coherence spectra (MEG/EEG)

Measurement methods (examples):

- $E(t)$: NADH fluorescence, FLIM, phosphorescence
- $R(t)$: GCaMP, ion microelectrodes, FRET sensors
- $D(t)$: cross-frequency coupling, multiscale entropy (EEG/MEG)

4. Comparison to Existing Theories

Theory	Main Critique	ASI Strength
IIT	Abstract, hard to measure	Direct physiological coupling (ATP/ Ca^{2+})
GWT	Neglects metabolic basis	Dynamically explanatory, energetically grounded
RPT	Pure complexity model	Explicit biological mechanism

Autocatalysis is not metaphorical, but refers to cyclic, feedback-coupled processes (e.g., ATP recycling, glycolysis, Ca^{2+} regulation), which are catalytically modulated by external stimuli.

5. Phenomenological Supplement

The question of the “hard problem” is misleading because it presupposes a dualistic background. In the phenomenological tradition (Husserl), it becomes clear: We are not observers of our consciousness, but its manifestation. Qualia are no mystery – they are the form in which a living, self-regulating system experiences itself.

Thus, when a stimulus (e.g., music) “hooks into” a prestructured oscillatory dynamic, this is not a physical coupling process, but an integration into an autocatalytic pattern. Consciousness arises when such

patterns not only exist, but are recursively stable – and cannot be dissolved into separate subsystems at any point.

6. Loss of Consciousness through Systemic Disruption

6.1 Hyperthermia

- Mechanism: protein denaturation, membrane damage
- Consequence: ATP loss, disturbance of ion conductance
- → ASI↓ (E↓, R↓, D↓)

6.2 Traumatic Brain Injury

- Mechanism: calcium overload, excitotoxic stress
- Consequence: disintegration despite local activity
- → ASI↓ (R↓, D↓)

6.3 Hypoxia

- Mechanism: ATP collapse due to O₂ deficiency
- Consequence: standstill of all energy-dependent processes
- → ASI↓ (E↓, R↓)

Interpretation: Loss of consciousness is not passive, but an expression of disrupted autocatalytic coherence.

7. Local Manifestation – Systemic Condition

Although consciousness arises in the brain, it depends on peripheral regulatory processes:

Bodily System	Influence on ASI
Cardiovascular	Oxygen supply → E
Respiration	pCO ₂ /pO ₂ → neuronal excitability (R, E)
Temperature regulation	Heat → membrane damage (R, D)
Neurohormones	Oscillation modulation (D, R)

These systems enable, but do not generate, consciousness – they merely stabilize the central autocatalytic processes.

7.1 Localization and Measurability of Causal Collapse

The Autocatalytic Stability Index (ASI) is only a meaningful marker of causal collapse – and thus of the presence of consciousness – where actual convergent integration of different information streams occurs. This is especially the case in the association areas of the brain, where multimodal sensory, cognitive, and motor signals are integrated at the cellular level.

In primary sensory or isolated cell structures, where only unimodal or weakly integrated signals are processed, the ASI remains low – the prerequisite for a collapse-like fusion of functional clusters is missing. Consciousness is thus tied to associative integration both at the network and the cellular level.

Experimental tests of the model must therefore focus on these areas to empirically demonstrate the causal collapse and its cellular markers.

8. Further Questions

- Scaling: Can glial or subcortical networks also carry an ASI?
 - ASI calibration: For clinical diagnostics (e.g., coma)?
 - Evolution: Are there rudimentary ASI forms in decentralized animals (e.g., Cnidaria)?
 - Sedation: Does propofol act via E, R, or D?
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Conclusion

The Autocatalytic Stability Index (ASI) operationalizes a new paradigm: consciousness as an expression of metabolic, recursive stability. Causal collapse is not a metaphysical entity, but a physiological threshold state of systemic integration – specifically tied to the sites where convergent associative integration occurs. Thus, the ASI provides a verifiable, interdisciplinary foundation for future empirical research.

Selected References

Northoff, G. (2016). *Neuro-Philosophy and the Healthy Mind*. Norton.

Northoff, G. & Huang, Z. (2017). "How do the brain's time and space mediate consciousness?" *Neuroscience of Consciousness*, 2017(1).

Xiao, D. et al. (2017). "Gamma activity does not predict conscious perception." *J. Neurosci.*

Yellen, G. (2016). "Fueling thought: Management of glycolysis and oxidative phosphorylation in neurons." *J. Cell Biol.*

Heiney, K. et al. (2020). "Astrocytic calcium and ATP regulation." *Glia*.

Tagliazucchi, E. et al. (2016). "Large-scale signatures of unconsciousness are consistent with a departure from critical dynamics." *J. R. Soc. Interface*.