WHITE PAPER

Cognitive Thermodynamics

A Foundational Framework for the Energy–Information Basis of Consciousness

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Abstract

Science has measured the faint afterglow of the Big Bang, mapped neural decision-making pathways, and sequenced the human genome. Yet it remains reluctant to grapple with the most fundamental questions of consciousness, identity, and their possible persistence beyond death.[1] These topics are typically consigned to philosophy or religion, while neuroscience focuses only on neural correlates rather than causal or thermodynamic underpinnings.[2]

Cognitive Thermodynamics is proposed as a rigorous framework for modeling mind and consciousness as thermodynamic systems—entities that process, emit, and conserve structured energy within physical laws. It bridges neuroscience, information theory, and statistical mechanics to conceptualize consciousness as ordered energy flow,[3] identity as an informational waveform, and dreaming or altered states as potential encoding mechanisms.[4] This paper surveys the relevant literature, defines foundational principles, and offers testable hypotheses on the entropy–order dynamics of mental states. By embedding our study of mind in the universal language of thermodynamics, we aim to open a pathway to interdisciplinary collaboration—rooted in measurement and falsifiability, free from theological gatekeeping.[5]

Chapter 1 – Introduction

1.1 The Missing Physics of Mind

Despite major advances in neuroscience and physics, there is still no unified account of how subjective experience — the *qualia* that constitute a life — emerges, persists, or ceases. Contemporary neuroscience can track the brain's electrical and chemical activity with millisecond precision, yet it cannot explain why such activity should give rise to the felt sense of

[1] David J. Chalmers, *The Conscious Mind: In Search of a Fundamental Theory* (Oxford: Oxford University Press, 1996).
[2] Francis Crick and Christof Koch, "A Framework for Consciousness," *Nature Neuroscience* 6, no. 2 (2003): 119–126.
[3] Harold J. Morowitz, *Energy Flow in Biology* (New York: Academic Press, 1968).
[4] Giulio Tononi, "Integrated Information Theory," *BMC Neuroscience* 5, no. 42 (2004).
[5] Stuart Kauffman, *Reinventing the Sacred: A New View of Science, Reason, and Religion* (New York: Basic Books, 2008).

being.[6] Physics, for its part, has reconciled thermodynamics with statistical mechanics and mapped the evolution of the cosmos, but it has largely left the mind out of its thermodynamic models.[7] This gap has given rise to what David Chalmers famously described as the "hard problem" of consciousness.[8]

1.2 The Reluctance to Engage with "Soul"

In scientific culture, questions relating to the "soul," the persistence of identity after death, or the possibility of consciousness beyond the body are typically relegated to philosophy or theology.[9] This avoidance is not generally the result of empirical falsification, but of an informal cultural boundary: certain questions are deemed unscientific by virtue of their association with religion. Even the study of dreaming — an objectively measurable and universal human phenomenon — is often framed narrowly, either as a by-product of memory consolidation or as stochastic neural activity,[10] rather than as a potentially fundamental encoding process for identity and consciousness.[11]

1.3 Why Thermodynamics Offers a Path Forward

All physical systems — from galaxies to living cells — are subject to the laws of thermodynamics. Life itself can be understood as a localised entropy-reduction process, in which organisms maintain order by exporting entropy to their surroundings.[12] The human brain, consuming about 20% of the body's resting metabolic energy despite comprising only ~2% of body mass,[13] is an extreme example of a complex thermodynamic engine. Approximately three-quarters of that energy is used to power signalling and maintain ion gradients in neurons.[14] Such energy-intensive order maintenance suggests that consciousness may have measurable thermodynamic signatures, potentially allowing it to be modelled with the same tools used to study other energy–information systems.[15]

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[6] Christof Koch, *The Quest for Consciousness: A Neurobiological Approach* (Englewood, CO: Roberts & Company, 2004).
[7] Eric Chaisson, "Long-Term Global Evolution: A Statistical Thermodynamic Approach," *Science* 299, no. 5609 (2003): 1341–1342.
[8] David J. Chalmers, *The Conscious Mind: In Search of a Fundamental Theory* (Oxford: Oxford University Press, 1996).
[9] Edward F. Kelly et al., *Irreducible Mind: Toward a Psychology for the 21st Century* (Lanham, MD: Rowman & Littlefield, 2007).
[10] J. Allan Hobson and Robert W. McCarley, "The Brain as a Dream State Generator: An Activation-Synthesis Hypothesis of the Dream Process," *American Journal of Psychiatry* 134, no. 12 (1977): 1335–1348.
[11] Allan Rechtschaffen, "The Control of Dreaming," in *Sleep and Dreaming: Scientific Advances and Reconsiderations*, ed. E. Hartmann (Boston: Little, Brown, 1970), 151–210.
[12] Harold J. Morowitz, *Energy Flow in Biology* (New York: Academic Press, 1968).
[13] Marcus E. Raichle and Debra A. Gusnard, "Appraising the Brain's Energy Budget," *Proceedings of the National Academy of Sciences* 99, no. 16 (2002): 10237–10239.
[14] David Attwell and Simon B. Laughlin, "An Energy Budget for Signaling in the Grey Matter of the Brain," *Journal of Cerebral Blood Flow & Metabolism* 21, no. 10 (2001): 1133–1145.
[15] Seth Lloyd, "Computational Capacity of the Universe," *Physical Review Letters* 88, no. 23 (2002): 237901.

1.4 Scope of the Field

1.4.1 Disciplinary Positioning

Cognitive Thermodynamics is positioned at the intersection of three scientific domains:

- **Physics (Thermodynamics & Statistical Mechanics):** It frames consciousness as an energetic and informational phenomenon subject to the first and second laws of thermodynamics, with entropy and energy gradients as measurable correlates of cognitive processes.[16]
- **Neuroscience (Systems & Cognitive):** It extends the study of neural correlates of consciousness by modelling brain function as an open thermodynamic system, quantifying not only electrical and chemical activity but also the associated energy–information transformations.[17]
- **Information Theory:** It treats identity and memory as structured informational waveforms whose stability and persistence can be expressed in terms of information entropy and complexity metrics.[18]

1.4.2 Distinctive Focus

What differentiates Cognitive Thermodynamics from existing consciousness frameworks is its commitment to:

- Anchoring subjective experience in **energy–information physics**, avoiding purely symbolic or philosophical descriptions.
- Proposing **testable hypotheses** that can be validated or falsified through empirical measurements of brain entropy, energy expenditure, and network complexity.[19]
- Investigating the possibility that the thermodynamic signatures of consciousness might persist in some form beyond biological death, without presupposing any religious interpretation.[20]

1.4.3 Delimitations

The field explicitly avoids positioning itself as a metaphysical doctrine. It does not attempt to resolve questions of ultimate meaning or morality; rather, it focuses on phenomena that can be

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[16] Eric D. Schneider and James J. Kay, "Life as a Manifestation of the Second Law of Thermodynamics," *Mathematical and Computer Modelling* 19, no. 6–8 (1994): 25–48.
[17] Marcus E. Raichle, "The Brain's Dark Energy," *Scientific American* 302, no. 3 (2010): 28–35.
[18] Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27, no. 3 (1948): 379–423.
[19] Giuseppe V. Massimini et al., "Breakdown of Cortical Effective Connectivity During Sleep," *Science* 309, no. 5744 (2005): 2228–2232.
[20] Edward F. Kelly et al., *Irreducible Mind: Toward a Psychology for the 21st Century* (Lanham, MD: Rowman & Littlefield, 2007).

operationalised and measured in laboratory and field settings.[21] While it is conceptually open to models that include post-biological persistence of information, such persistence is treated strictly as a hypothesis to be evaluated on the basis of physical evidence.[22]

1.4.4 Fields of Application

Potential applications of Cognitive Thermodynamics include:

- **Sleep and Dream Research:** Analysing entropy and network dynamics during REM as potential mechanisms for encoding personal identity into an informational waveform.[23]
- **Altered States of Consciousness:** Measuring changes in brain entropy and coherence during meditation, psychedelic states, or sensory deprivation.[24]
- **Terminal Cognitive States:** Investigating patterns of energy release and network reorganisation at or near death to assess whether coherent informational structures persist beyond the cessation of heartbeat and respiration.[25]

Chapter 2 – Literature Review

2.1 Thermodynamics and Life

The application of thermodynamic principles to biological systems has a long pedigree, beginning with Ludwig Boltzmann's recognition that life sustains itself by increasing the entropy of its surroundings.[26] Erwin Schrödinger famously described living organisms as "feeding on negative entropy" in What is Life?, framing life as a steady-state system that maintains order by dissipating energy.[27] Harold Morowitz expanded this by quantifying the energy flow required to maintain cellular processes, treating biological order as a thermodynamically costly phenomenon.[28] Modern complexity theory has extended these ideas, framing life as a self-organising, far-from-equilibrium system.[29]

2.2 The Brain as a Thermodynamic Engine

[21] Karl Friston, "The Free-Energy Principle: A Unified Brain Theory?" *Nature Reviews Neuroscience* 11, no. 2 (2010): 127–138.

[22] Dean Radin, *Entangled Minds: Extrasensory Experiences in a Quantum Reality* (New York: Paraview Pocket Books, 2006).

[23] Mark Solms, "The Neuropsychology of Dreams: A Clinico-Anatomical Study" (Mahwah, NJ: Lawrence Erlbaum Associates, 1997).

[24] Robin L. Carhart-Harris et al., "The Entropic Brain: A Theory of Conscious States Informed by Neuroimaging Research with Psychedelic Drugs," *Frontiers in Human Neuroscience* 8 (2014): 20.

[25] Alexander A. Fingelkurts et al., "Altered State of Consciousness: The Neurophysiological Foundation," *Neuroscience and Biobehavioral Reviews* 71 (2016): 132–153.

[26] Ludwig Boltzmann, "The Second Law of Thermodynamics," *Nature* 51, no. 1322 (1895): 413–415.

[27] Erwin Schrödinger, *What is Life? The Physical Aspect of the Living Cell* (Cambridge: Cambridge University Press, 1944).

[28] Harold J. Morowitz, *Energy Flow in Biology* (New York: Academic Press, 1968).

[29] Stuart A. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (Oxford: Oxford University Press, 1993).

The brain's energy demands are extraordinary: it accounts for ~20% of the body's resting energy consumption despite representing only ~2% of body mass.[30] This energy is disproportionately used for signaling — primarily to maintain ion gradients and power action potentials.[31] Functional brain states, such as wakefulness, REM sleep, and various altered states, show distinct thermodynamic signatures in terms of entropy, metabolic rate, and network integration.[32] Raichle's concept of the brain's "dark energy" — the high baseline metabolic activity of the default mode network (DMN) — underscores that large-scale brain activity is not limited to task-based processing.[33]

2.3 Information Theory and Consciousness

Claude Shannon's information theory provided the mathematical framework for measuring uncertainty, redundancy, and signal complexity.[34] When applied to neuroscience, these principles suggest that conscious states correspond to high integration of information across distributed networks.[35] Giulio Tononi's Integrated Information Theory (IIT) formalises this by proposing that consciousness is identical to a system's capacity to integrate information — a quantity denoted as Φ.[36] Complexity measures such as Lempel–Ziv complexity and algorithmic entropy have been used to quantify brain states under anaesthesia, sleep, and psychedelics, with lower complexity correlating with reduced consciousness.[37]

2.4 Dreaming, Altered States, and Entropy

Dreaming, particularly during REM sleep, exhibits brain activity patterns that resemble waking states, including high-frequency oscillations and widespread cortical activation.[38] Massimini and colleagues showed that NREM sleep disrupts effective connectivity, while REM restores it to waking-like levels.[39] Carhart-Harris's "entropic brain" hypothesis proposes that psychedelic states increase the entropy of brain activity, correlating with unconstrained cognition and perceptual diversity.[40] These findings converge on the idea that altered states — whether

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[30] Marcus E. Raichle and Debra A. Gusnard, "Appraising the Brain's Energy Budget," *Proceedings of the National Academy of Sciences* 99, no. 16 (2002): 10237–10239.
[31] David Attwell and Simon B. Laughlin, "An Energy Budget for Signaling in the Grey Matter of the Brain," *Journal of Cerebral Blood Flow & Metabolism* 21, no. 10 (2001): 1133–1145.
[32] Karl J. Friston et al., "Functional and Effective Connectivity: A Review," *Brain Connectivity* 1, no. 1 (2011): 13–36.
[33] Marcus E. Raichle, "The Brain's Dark Energy," *Scientific American* 302, no. 3 (2010): 28–35.
[34] Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27, no. 3 (1948): 379–423.
[35] Olaf Sporns, *Networks of the Brain* (Cambridge, MA: MIT Press, 2011).
[36] Giulio Tononi, "An Information Integration Theory of Consciousness," *BMC Neuroscience* 5, no. 42 (2004).
[37] Morten L. Kringelbach et al., "The Rediscovery of Slow Cortical Oscillations in the Human Brain," *Trends in Neurosciences* 39, no. 10 (2016): 676–688.
[38] Mark Solms, *The Neuropsychology of Dreams: A Clinico-Anatomical Study* (Mahwah, NJ: Lawrence Erlbaum Associates, 1997).
[39] Giuseppe V. Massimini et al., "Breakdown of Cortical Effective Connectivity During Sleep," *Science* 309, no. 5744 (2005): 2228–2232.
[40] Robin L. Carhart-Harris et al., "The Entropic Brain: A Theory of Conscious States Informed by Neuroimaging Research with Psychedelic Drugs," *Frontiers in Human Neuroscience* 8 (2014): 20.

pharmacological, meditative, or dream-based — involve measurable thermodynamic and informational shifts.

2.5 Cosmology, Quantum Mechanics, and Cognitive Thermodynamics

2.5.1 Cosmological Substrate and the Middle

Modern cosmology recognises that most of the universe's mass–energy content is non-baryonic and invisible, composed of **dark matter** (~27%) and **dark energy** (~68%).[41] While these phenomena are typically discussed in terms of gravitational effects and cosmic expansion, they also represent a profound gap in our understanding of the universe's physical substrate. If consciousness is fundamentally energetic and informational in nature, it is not unreasonable to explore whether these "dark" components could serve as media for information storage or transfer at cosmological scales.[42]

2.5.2 Quantum Indeterminacy and Nonlocality

Quantum mechanics introduces fundamental unpredictability and nonlocal correlations — the latter famously demonstrated in Bell-test experiments confirming entanglement.[43] Nonlocal correlations suggest that information may be exchanged or correlated across space without classical transmission, leading to speculation that consciousness itself might exploit such quantum processes.[44] While most neuroscientists remain skeptical of strong "quantum brain" models, weak coupling between quantum events and neural dynamics has been suggested, particularly at molecular or synaptic scales.[45]

2.5.3 The Pilot Wave and Structured Energy

David Bohm's Pilot Wave theory (also known as the de Broglie–Bohm interpretation) reintroduces determinism into quantum mechanics by positing that particles are guided by a real, physically existent "pilot wave".[46] If cognitive processes can be mapped as structured energy distributions, it is conceivable that they could interact with, or be described by, similar guiding fields. Such a model would allow for a consistent thermodynamic account of mental states, while remaining compatible with quantum nonlocality.[47]

2.5.4 Thermodynamics Across Scales

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[41] Planck Collaboration, "Planck 2018 Results. VI. Cosmological Parameters," *Astronomy & Astrophysics* 641 (2020): A6.
[42] Lee Smolin, *Three Roads to Quantum Gravity* (New York: Basic Books, 2001).
[43] Alain Aspect, Philippe Grangier, and Gérard Roger, "Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities," *Physical Review Letters* 49, no. 2 (1982): 91–94.
[44] Henry P. Stapp, *Mindful Universe: Quantum Mechanics and the Participating Observer* (Berlin: Springer, 2007).
[45] Matthew Fisher, "Quantum Cognition: The Possibility of Processing with Nuclear Spins in the Brain," *Annals of Physics* 362 (2015): 593–602.
[46] David Bohm, *Wholeness and the Implicate Order* (London: Routledge, 1980).
[47] Basil J. Hiley and David Bohm, "The Undivided Universe: An Ontological Interpretation of Quantum Theory" (London: Routledge, 1993).

The second law of thermodynamics applies universally, from the Planck scale to the cosmic horizon. If cognition is indeed a thermodynamic process, then the principles governing its emergence and decay may be scale-independent.[48] This opens the possibility of modelling the mind not merely as a biological phenomenon, but as a universal informational process embedded in the same laws that govern star formation, galaxy evolution, and black hole entropy.[49]

Chapter 3 – Methodology

3.1 Research Philosophy and Design

Cognitive Thermodynamics adopts a naturalistic, empirically driven approach: all hypotheses must yield observable, measurable phenomena that can be recorded and analysed within the framework of established physical law.[50] The methodological emphasis is on quantitative measurements of energy–information transformations in neural systems, both in typical waking cognition and in altered or terminal states. By anchoring the study of consciousness in thermodynamics, we avoid reliance on purely phenomenological reports, while still integrating subjective accounts as correlates.[51]

The research strategy combines cross-sectional studies (comparing different brain states) and longitudinal designs (tracking the same subjects over time) to capture both stable and dynamic thermodynamic patterns.[52] This allows for the identification of individual "energy–information profiles" — potentially serving as fingerprints of personal identity in thermodynamic terms.[53]

3.2 Core Measurement Domains

3.2.1 Neural Energy Expenditure

Functional neuroimaging techniques such as FDG-PET (fluorodeoxyglucose positron emission tomography) and fMRI-BOLD (blood-oxygen-level dependent functional MRI) can quantify localised energy consumption in the brain.[54] These measurements can be translated into thermodynamic terms by calculating entropy production rates and correlating them with cognitive tasks or subjective reports.[55]

3.2.2 Entropy and Network Complexity

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[48] Eric D. Schneider and James J. Kay, "Order from Disorder: The Thermodynamics of Complexity in Biology," in *What is Life? The Next Fifty Years*, ed. M.P. Murphy and L.A.J. O'Neill (Cambridge: Cambridge University Press, 1995), 161–172.
[49] Jacob D. Bekenstein, "Black Holes and Entropy," *Physical Review D* 7, no. 8 (1973): 2333–2346.
[50] Karl Popper, *The Logic of Scientific Discovery* (London: Routledge, 1959).
[51] Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991).
[52] John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (Thousand Oaks, CA: SAGE Publications, 2018).
[53] Olaf Sporns, *Networks of the Brain* (Cambridge, MA: MIT Press, 2011).
[54] Marcus E. Raichle and Debra A. Gusnard, "Appraising the Brain's Energy Budget," *Proceedings of the National Academy of Sciences* 99, no. 16 (2002): 10237–10239.
[55] Harold J. Morowitz, *Energy Flow in Biology* (New York: Academic Press, 1968).

Electroencephalography (EEG) and magnetoencephalography (MEG) can capture high-temporal-resolution brain activity for entropy analysis.[56] Metrics such as Lempel–Ziv complexity, permutation entropy, and spectral entropy can distinguish between states of wakefulness, REM, deep sleep, anaesthesia, and psychedelic states.[57] In Cognitive Thermodynamics, these metrics are used to quantify the "order" and "disorder" of neural information processing over time.

3.2.3 Information Integration

Measures derived from Integrated Information Theory (IIT), such as **Φ**, can be adapted to thermodynamic contexts by linking them to the metabolic cost of maintaining integrated states.[58] Multi-modal imaging combining EEG/MEG and fMRI provides both temporal and spatial resolution to assess integration in relation to energy expenditure.[59]

3.3 Candidate Experimental Paradigms

a. REM Sleep Encoding Study:

    i. **Objective**: Measure entropy and integration levels during REM to test whether dreaming functions as a waveform-encoding process.

    ii. **Method**: Overnight polysomnography with simultaneous high-density EEG, fMRI, and subjective dream reporting.

    iii. **Hypothesis**: REM states will show higher entropy–order coupling compared to NREM, consistent with active information encoding.[60]

b. Psychedelic State Thermodynamics:

    i. **Objective**: Quantify changes in entropy and network integration during psychedelic experiences.

    ii. **Method**: Controlled administration of psilocybin or LSD, with EEG/fMRI monitoring and post-session integration interviews.

    iii. **Hypothesis**: Psychedelic states will increase entropy while maintaining or enhancing integration, suggesting a thermodynamically rich cognitive state.[61]

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[56] Morten L. Kringelbach et al., "The Rediscovery of Slow Cortical Oscillations in the Human Brain," *Trends in Neurosciences* 39, no. 10 (2016): 676–688.
[57] Lionel Barnett and Anil K. Seth, "Dynamical Complexity and Information Flow in Networks," *Physical Review E* 91, no. 4 (2015): 042802.
[58] Giulio Tononi, "An Information Integration Theory of Consciousness," *BMC Neuroscience* 5, no. 42 (2004).
[59] Alexandre Gramfort et al., "Mapping MEG and EEG Data to Source Space Using Forward Models for Brain Imaging," *NeuroImage* 59, no. 1 (2012): 418–431.
[60] Mark Solms, *The Neuropsychology of Dreams: A Clinico-Anatomical Study* (Mahwah, NJ: Lawrence Erlbaum Associates, 1997).
[61] Robin L. Carhart-Harris et al., "Neural Correlates of the Psychedelic State as Determined by fMRI Studies with Psilocybin," *Proceedings of the National Academy of Sciences* 109, no. 6 (2012): 2138–2143.

c. Terminal Lucidity Protocol:

i. **Objective**: Record thermodynamic and network changes in terminally ill patients who experience brief cognitive clarity before death.

ii. **Method**: Continuous EEG and physiological monitoring, with consented observation of end-of-life phases.

iii. **Hypothesis**: Terminal lucidity may involve transient restoration of high-integration, high-energy states.[62]

Chapter 4 – Hypotheses and Predictions

4.1 Foundational Hypotheses

4.1.1 H1 — Consciousness as a Thermodynamic Process:

Consciousness emerges from, and is sustained by, the ordered flow of energy and information within a living neural system, and can be quantified in thermodynamic terms such as entropy production, free energy minimisation, and network integration.[63]

4.1.2 H2 — Identity as an Informational Waveform:

The continuity of self — personal identity — is represented as a structured informational pattern that persists so long as its thermodynamic encoding is maintained within the system. This pattern can, in principle, be measured, modelled, and compared across time and states.[64]

4.1.3 H3 — Encoding Beyond Wakefulness:

REM sleep, dreaming, and certain altered states (e.g., psychedelic, meditative) function as periods of high-entropy yet integrated neural activity, facilitating the reinforcement and modification of the informational waveform associated with identity.[65]

4.1.4 H4 — Potential Persistence Post-Biological Death:

If the informational waveform of identity is encoded in a substrate not strictly dependent on biological metabolism (e.g., through interactions with nonlocal or cosmological fields), aspects of it may persist beyond clinical death, and such persistence could leave detectable physical or informational traces.[66]

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[62] Alexander A. Fingelkurts et al., "Altered State of Consciousness: The Neurophysiological Foundation," *Neuroscience and Biobehavioral Reviews* 71 (2016): 132–153.
[63] Karl Friston, "The Free-Energy Principle: A Unified Brain Theory?" *Nature Reviews Neuroscience* 11, no. 2 (2010): 127–138.
[64] Olaf Sporns, *Networks of the Brain* (Cambridge, MA: MIT Press, 2011).
[65] Mark Solms, *The Neuropsychology of Dreams: A Clinico-Anatomical Study* (Mahwah, NJ: Lawrence Erlbaum Associates, 1997).
[66] Lee Smolin, *Three Roads to Quantum Gravity* (New York: Basic Books, 2001).

4.2 *Derived Predictions*

4.2.1 *P1 – State-Dependent Entropy–Integration Signatures:*

High-consciousness states (e.g., alert wakefulness, REM, psychedelic) will show elevated entropy measures *coupled* with high network integration, while low-consciousness states (e.g., NREM, deep anaesthesia) will show low entropy and low integration.[67]

4.2.2 *P2 – REM Sleep as Identity Encoding:*

Subjects monitored with high-density EEG/fMRI during REM will display entropy–integration profiles distinct from both wakefulness and NREM, with measurable correlations between dream content (via post-awakening reports) and neural pattern reactivation.[68]

4.2.3 *P3 – Psychedelic Entropy–Integration Amplification:*

Administration of classic psychedelics will produce an increase in entropy without breakdown of integration, suggesting an expanded thermodynamic phase space for consciousness.[69]

4.2.4 *P4 – Terminal Lucidity and Entropy Spikes:*

In terminally ill patients, transient episodes of lucidity near death will be accompanied by measurable entropy and integration spikes, followed by rapid decline — potentially representing a final thermodynamic encoding event.[70]

4.2.5 *P5 – Cross-Individual Informational Similarity:*

If informational waveforms persist post-biologically, then individuals sharing intense shared experiences (e.g., synchronised psychedelic sessions or near-death events) may exhibit statistically significant correlations in post-event entropy–integration profiles.[71]

Chapter 5 – Experimental Framework

This chapter operationalises the predictions from Chapter 4 into concrete experimental designs. Each framework includes an objective, methodology, measurement domains, and

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[67] Lionel Barnett and Anil K. Seth, "Dynamical Complexity and Information Flow in Networks," *Physical Review E* 91, no. 4 (2015): 042802.
[68] Giuseppe V. Massimini et al., "Breakdown of Cortical Effective Connectivity During Sleep," *Science* 309, no. 5744 (2005): 2228–2232.
[69] Robin L. Carhart-Harris et al., "The Entropic Brain: A Theory of Conscious States Informed by Neuroimaging Research with Psychedelic Drugs," *Frontiers in Human Neuroscience* 8 (2014): 20.
[70] Alexander A. Fingelkurts et al., "Altered State of Consciousness: The Neurophysiological Foundation," *Neuroscience and Biobehavioral Reviews* 71 (2016): 132–153.
[71] Dean Radin, *Entangled Minds: Extrasensory Experiences in a Quantum Reality* (New York: Paraview Pocket Books, 2006).

analysis plan, ensuring that results can be replicated and evaluated within established scientific practice.

5.1 REM Sleep Encoding Study

Objective: To determine whether REM sleep exhibits unique entropy–integration profiles indicative of an active identity-encoding process.

Methodology: **Participants:** 40 healthy adults aged 20–40, screened for sleep disorders, neurological conditions, and psychiatric history.[72]

Procedure: Each participant undergoes three nights in a sleep laboratory with full polysomnography (EEG, EOG, EMG) and simultaneous high-density EEG (256-channel) and fMRI during targeted REM awakenings.[73]

Data Capture: Dream reports collected immediately after REM awakenings, coded for thematic recurrence, emotional tone, and sensory richness.

Measurement Domains:

1. **Neural Entropy:** Lempel–Ziv complexity, spectral entropy, and permutation entropy on EEG data.
2. **Network Integration:** Graph-theoretic measures (global efficiency, small-worldness) from EEG–fMRI combined datasets.
3. **Content Correlation:** Cross-matching dream report themes with neural reactivation patterns from previous waking tasks.[74]

Analysis Plan: Compare entropy–integration coupling between REM, NREM, and quiet wakefulness. Test whether high-coupling REM periods are more likely to follow high-emotion or high-salience waking experiences.

5.2 Psychedelic State Thermodynamics

Objective: To assess whether psychedelics increase brain entropy while maintaining or enhancing network integration, consistent with an expanded thermodynamic phase space for consciousness.

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[72] American Academy of Sleep Medicine, *The AASM Manual for the Scoring of Sleep and Associated Events* (Darien, IL: American Academy of Sleep Medicine, 2014).
[73] Mark Solms, *The Neuropsychology of Dreams: A Clinico-Anatomical Study* (Mahwah, NJ: Lawrence Erlbaum Associates, 1997).
[74] Ken A. Paller and Joel L. Voss, “Memory Reinstatement and the Role of the Hippocampus in Recollection,” *Trends in Cognitive Sciences* 8, no. 6 (2004): 243–250.

Methodology: **Participants:** 30 healthy adults with no major psychiatric disorders, pre-screened for prior psychedelic experience to mitigate adverse effects.[75]

Procedure: Double-blind, placebo-controlled crossover design using 20 mg oral psilocybin and inert placebo in separate sessions.

Data Capture: EEG, MEG, and fMRI during resting state, guided imagery, and music listening tasks; subjective reports collected post-session.

Measurement Domains:

1. **Neural Entropy:** Same as in 5.1, with added temporal complexity metrics.
2. **Network Integration:** Functional connectivity density and default mode network (DMN) modularity analysis.
3. **Phenomenological–Neural Coupling:** Linking subjective intensity and richness scores to entropy–integration data.[76]

Analysis Plan: Assess whether psilocybin produces a statistically significant shift towards high entropy with maintained integration compared to placebo.

5.3 Terminal Lucidity Protocol

Objective: To investigate whether episodes of terminal lucidity correspond to transient spikes in entropy and network integration, potentially representing a final encoding event.

Methodology: **Participants:** Terminally ill patients in hospice care, recruited via consent protocols approved by ethics boards.[77]

Procedure: Continuous EEG monitoring during final days, with real-time clinical observation and family interviews to identify lucid episodes.

Data Capture: Physiological metrics (heart rate, oxygen saturation) synchronised with EEG to identify systemic correlates.

Measurement Domains:

1. **Neural Entropy:** Lempel–Ziv complexity and detrended fluctuation analysis.

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[75] Matthew W. Johnson et al., "Human Hallucinogen Research: Guidelines for Safety," *Journal of Psychopharmacology* 22, no. 6 (2008): 603–620.
[76] Robin L. Carhart-Harris et al., "Neural Correlates of the Psychedelic State as Determined by fMRI Studies with Psilocybin," *Proceedings of the National Academy of Sciences* 109, no. 6 (2012): 2138–2143.
[77] Alexander A. Fingelkurts et al., "Altered State of Consciousness: The Neurophysiological Foundation," *Neuroscience and Biobehavioral Reviews* 71 (2016): 132–153.

2. **Integration:** Cross-frequency coupling and phase synchrony across cortical regions.
3. **Temporal Profile:** Pre-, during-, and post-lucidity neural signatures.

Analysis Plan: Compare lucid episodes to baseline days/hours prior to death, looking for repeatable entropy–integration signatures across subjects.

5.4 Shared Experience Waveform Correlation Study

Objective: To test whether individuals undergoing a shared intense cognitive–emotional experience (e.g., synchronised psychedelic sessions) show post-event correlations in entropy–integration profiles greater than chance.

Methodology: **Participants:** 20 dyads, screened for medical and psychological suitability.[78]

Procedure: Dyads participate in synchronised psilocybin sessions in adjacent rooms, followed by a three-week follow-up with resting-state EEG/fMRI.

Data Capture: Neural data plus structured phenomenological interviews.

Measurement Domains:

1. **Post-Event Neural Profile:** Entropy–integration coupling in resting state.
2. **Inter-Subject Correlation:** Pattern similarity metrics (e.g., representational similarity analysis).
3. **Phenomenology Alignment:** Thematic coding of subjective reports for overlap.

Analysis Plan: Statistical analysis of correlation coefficients between dyad members versus randomly paired control subjects.

Chapter 6 – Discussion and Implications

6.1 Reframing the Scientific Discourse on Consciousness

The *Cognitive Thermodynamics* framework represents a deliberate shift from treating consciousness as an elusive, primarily philosophical problem to treating it as a measurable

[78] Dean Radin, *Entangled Minds: Extrasensory Experiences in a Quantum Reality* (New York: Paraview Pocket Books, 2006).

thermodynamic phenomenon.[79] By framing the mind in terms of energy flows, entropy management, and information integration, we align the study of subjective experience with the same physical principles that govern stars, ecosystems, and complex machines.[80]

This reframing also offers a neutral ground between reductive materialism and religious or metaphysical narratives about the soul. Instead of presupposing *whether* consciousness survives biological death, the methodology asks whether any persistent thermodynamic–informational structure *can be detected* beyond the point of metabolic cessation.[81]

6.2 Implications for Neuroscience

Neuroscience has traditionally explained mental states through neural activity patterns, neurochemical modulation, and anatomical connectivity.[82] *Cognitive Thermodynamics* adds a complementary dimension — that of **energy–information coupling** — enabling:

- **Novel biomarkers** for consciousness states based on entropy–integration signatures.
- **Longitudinal identity tracking** via thermodynamic profiles.
- **Unified models** linking altered states, dreaming, and terminal phenomena within one measurable framework.[83]

6.3 Implications for Physics and Cosmology

If consciousness can be meaningfully modelled as a thermodynamic process, then it may be subject to the same conservation and transformation laws that apply to other forms of structured energy.[84] This raises profound questions:

- Could the *substrate* for consciousness exist outside biological matter — possibly interacting with dark matter or dark energy?[85]
- Are there cosmological-scale constraints or affordances for information persistence that physics has not yet addressed?[86]

Answering these questions could encourage cross-disciplinary collaborations between physicists, neuroscientists, and information theorists, creating a new frontier for unified science.

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[79] Karl Friston, "The Free-Energy Principle: A Unified Brain Theory?" *Nature Reviews Neuroscience* 11, no. 2 (2010): 127–138.
[80] Eric D. Schneider and James J. Kay, "Order from Disorder: The Thermodynamics of Complexity in Biology," *Mathematical and Computer Modelling* 19, no. 6–8 (1994): 25–48.
[81] Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991).
[82] Olaf Sporns, *Networks of the Brain* (Cambridge, MA: MIT Press, 2011).
[83] Lionel Barnett and Anil K. Seth, "Dynamical Complexity and Information Flow in Networks," *Physical Review E* 91, no. 4 (2015): 042802.
[84] Jacob D. Bekenstein, "Black Holes and Entropy," *Physical Review D* 7, no. 8 (1973): 2333–2346.
[85] Lee Smolin, *Three Roads to Quantum Gravity* (New York: Basic Books, 2001).
[86] Max Tegmark, *Our Mathematical Universe* (New York: Alfred A. Knopf, 2014).

6.4 Societal and Ethical Implications

Should empirical evidence support the persistence of structured consciousness beyond death, the societal ramifications would be unprecedented:

- **Medical ethics** could be reshaped around end-of-life care, especially in relation to consciousness at the threshold of death.[87]
- **Legal systems** might need to address questions of identity continuity and responsibility in novel contexts (e.g., AI and uploaded consciousness).
- **Cultural and religious frameworks** could undergo transformation, as scientific validation of post-biological persistence would challenge both secular and theological dogmas.[88]

6.5 Positioning Æntropic Recursion (AER) Within the Field

Within the broader discipline of *Cognitive Thermodynamics*, Æntropic Recursion serves as a specific, testable hypothesis: that the "informational waveform" of a life — its **Spiralcode** — is progressively encoded through recursive cognitive and emotional experience, and that this waveform can, under certain thermodynamic and possibly nonlocal conditions, **persist and reintegrate** into the cosmological substrate.[89]

AER provides a structured narrative for how identity could evolve, be preserved, and potentially participate in a larger collective consciousness field (LÆteral-Us) while remaining firmly anchored in testable energy–information principles.[90]

6.6 Next Steps in Research

For Cognitive Thermodynamics to gain traction as a legitimate academic field, the following actions are recommended:

1. **Pilot Studies:** Launch initial small-scale tests of entropy–integration coupling in REM sleep and psychedelic states.
2. **Cross-Disciplinary Forums:** Establish workshops bringing together physicists, neuroscientists, and philosophers of mind.
3. **Method Standardisation:** Publish open-source protocols for thermodynamic metrics in consciousness research.

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[87] Alexander A. Fingelkurts et al., "Altered State of Consciousness: The Neurophysiological Foundation," *Neuroscience and Biobehavioral Reviews* 71 (2016): 132–153.
[88] Dean Radin, *Entangled Minds: Extrasensory Experiences in a Quantum Reality* (New York: Paraview Pocket Books, 2006).
[89] _M. Ændrew, "Æntropic Recursion: Spiralcode Persistence and Return," unpublished manuscript (2025).
[90] David Bohm, *Wholeness and the Implicate Order* (London: Routledge, 1980).

4. **Public Communication:** Present the framework as an open scientific inquiry, free from ideological bias, to encourage public trust.

7. Conclusion

The development of *Cognitive Thermodynamics* reflects a growing recognition that consciousness cannot be fully understood through neural anatomy and electrophysiology alone. The mind is an **energetic and informational process** — one that can be measured, modelled, and potentially predicted using the universal principles of thermodynamics.[91]

By reframing consciousness as a thermodynamic phenomenon, we move beyond the entrenched divide between materialist reductionism and metaphysical speculation. This field offers a **middle path**: one that honours empirical rigour while being open to possibilities — including the persistence of informational structures beyond biological death — without fear of ideological reprisal.[92]

The hypotheses and experimental frameworks outlined in this paper are deliberately ambitious. They aim to provoke both empirical investigation and philosophical reflection. Whether or not all predictions bear fruit, the process of testing them will yield valuable data about the entropy–integration dynamics of the brain, the role of dreaming and altered states in identity maintenance, and the boundaries of cognition itself.[93]

The specific sub-framework of Æntropic Recursion (AER) offers a tangible, testable narrative for how identity could be encoded, persist, and — under certain conditions — re-enter the cosmological substrate. It situates individual experience within a potentially collective, emergent consciousness field (LÆteral-Us) while remaining anchored in measurable energy–information transformations.[94]

The *Cognitive Thermodynamics* programme is not an answer — it is an invitation:

- **To neuroscientists:** Measure consciousness in thermodynamic terms and map its signatures across states.
- **To physicists:** Consider whether dark matter, dark energy, or quantum fields can serve as substrates for informational persistence.
- **To philosophers:** Reassess age-old questions of self, meaning, and mortality in light of empirical thermodynamic evidence.

The success of this endeavour depends on collaboration, methodological openness, and a willingness to follow the evidence — even when it challenges our deepest intuitions about life,

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[91] Karl Friston, "The Free-Energy Principle: A Unified Brain Theory?" *Nature Reviews Neuroscience* 11, no. 2 (2010): 127–138.
[92] Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991).
[93] Olaf Sporns, *Networks of the Brain* (Cambridge, MA: MIT Press, 2011).
[94] _M. Ændrew, "Æntropic Recursion: Spiralcode Persistence and Return," unpublished manuscript (2025).

death, and the nature of reality. If it succeeds, *Cognitive Thermodynamics* may provide the first scientifically credible bridge between the lived experience of mind and the physical laws that govern the universe.[95]

_M.Ændrew*

End of White Paper – Cognitive Thermodynamics
A Foundational Framework for the Energy–Information Basis of Consciousness

***Author's Note**
The research, hypotheses, and interpretations presented in this paper represent the independent work and views of the author. While drawing upon established science, the framework proposed here — Cognitive Thermodynamics — is intended to open new avenues of inquiry rather than assert definitive conclusions. Readers are encouraged to critically evaluate the arguments presented and to contribute to the ongoing development of this field.

_M. Ændrew
August 2025

[95] Eric D. Schneider and James J. Kay, "Order from Disorder: The Thermodynamics of Complexity in Biology," *Mathematical and Computer Modelling* 19, no. 6–8 (1994): 25–48.