

The Ecology of Neoteny

Institutions, Entropy, and the Steady-State Civilization

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Abstract

This essay argues that civilisations creative longevity depends on the managed preservation of neotenous cognition—curiosity, play, and exploration—within protective institutional niches. Drawing on Alison Gopniks tripartite model of human intelligences (*Exploit, Explore, Empower*) [15, 16], it extends these ideas into an entropic framework, treating curiosity as a thermodynamic variable that must be subsidised and regulated. The result is a vision of the *steady-state civilisation*—a society that sustains perpetual exploration through equilibrium, not expansion. Empirical evidence from cognitive economics, cooperative game theory, and aging research is incorporated to show that social systems can maintain innovation and well-being without continuous material growth.

1 Introduction: Curiosity as a Civilizational Trait

Humanity's success derives less from strength or instinct than from the peculiar persistence of juvenile cognition. Traits such as curiosity, hyperfocus, and imaginative play—adaptive in children but maladaptive in isolation—are preserved in adults through social and institutional care. Civilisation, in this sense, is a machinery for managing prolonged immaturity [15].

This essay examines how societies sustain and regulate these neotenous modes of thought through economic and thermodynamic mechanisms. The university, the laboratory, and the studio are not accidents of culture; they are engineered sanctuaries where curiosity may safely consume entropy. Such institutions act as what Georgescu-Roegen [13] called “entropy converters”—systems that absorb disorder locally to preserve order globally.

2 Neoteny and Institutional Scaffolding

Biologically, neoteny is the retention of juvenile traits into adulthood. Cognitively, it manifests as a preference for exploration over exploitation—a willingness to suspend immediate reward in pursuit of novel information. Such tendencies are energetically expensive and socially destabilising unless buffered by structured environments [16].

Academic and artistic institutions perform this buffering function. They absorb the metabolic cost of curiosity by shielding practitioners from the demands of immediate

utility. In this sense, universities serve as *cognitive sanctuaries*, permitting socially useful maladaptation.

Supervision, funding, and evaluation act as homeostatic controls—the equivalents of parental oversight in a developmental ecology. Within these niches, maladaptive curiosity becomes a renewable source of informational order, an argument reminiscent of Morins systemic complexity [21] and Capra and Luisi's concept of cultural metabolism [4].

3 Corollaria Neotenica: Scaling Exploration in an Entropic Society

The preservation of exploratory cognition at scale presents an entropic dilemma: how to sustain freedom without disorder. Five corollaries follow.

3.1 The Maladaptation of Universal Neoteny

Curiosity is individually costly. A society in which every citizen behaves as a researcher would rapidly deplete its reserves of order. Neoteny must remain selective—a minority trait protected by structure [13].

$$\forall P \in \text{population}, f_{\text{neoteny}}(P) \rightarrow 1 \Rightarrow \frac{dS_{\text{society}}}{dt} \gg 0.$$

Exploration must be coupled to systems of care that reabsorb its entropic residue.

3.2 Universal Income as Entropic Buffer

A universal basic income can function as an entropy buffer, granting time for curiosity while maintaining social equilibrium. Yet income alone is insufficient; exploration must be linked to informational efficiency. This idea echoes Dalys proposals for moral limits to growth [6, 7] and Illich's call for *convivial tools* that empower without overextension [18].

$$\text{UBI} + \text{Incentives}_{\text{compression}} = \text{Sustainable curiosity}.$$

Curiosity without compression decays into noise.

3.3 The Geozotic Lottery

Innovation rewards should diffuse rather than concentrate. A proposed *Geozotic Lottery* distributes stochastic bonuses to individuals near the origin of invention, spatially or socially:

$$R(x) = R_0 e^{-\lambda d(x, x_0)},$$

where $d(x, x_0)$ denotes social or geographic distance. This mechanism spreads creative benefit through the community, encouraging shared investment in novelty—an echo of Boulding's vision of the “Spaceship Earth” economy as a closed feedback ecology [2].

3.4 Selective Cognitive Freedom

Not all individuals thrive in open-ended exploration. Routine, care, and stability remain essential. A healthy society maintains a spectrum of cognitive roles: some explore, others preserve. This division mirrors ecological differentiation and maintains systemic resilience [4, 8].

Diversity of cognitive roles \Rightarrow Resilience of civilisation.

3.5 Civilisation as Extended Ontogeny

Civilisation as a whole can be seen as a prolonged youth supported by an elder infrastructure. Automation assumes exploitative labour; humans return to exploration and care. The question becomes: who, or what, will serve as elders for a self-perpetuating youth? Illich [18] and Nussbaum [23] suggest that care, not growth, must become the new criterion of maturity.

4 Operationalizing Entropic Ethics

To transform symbolic equalities into measurable predictions, an entropy efficiency index is introduced:

$$\eta_S = \frac{\Delta I}{\Delta E},$$

where ΔI represents information gain (e.g., measured via patent filings, scientific publications, validated discoveries, or novel problem solutions) and ΔE denotes energy cost (monetary expenditure, time allocation, or metabolic equivalents). Institutional subsidies, including universal basic income and targeted grants, aim to maximise η_S by reducing the denominator while preserving or enhancing the numerator. This operationalisation aligns with cognitive economics models that quantify exploratory returns [12] and cultural evolution studies demonstrating efficiency gains under resource security [17].

Empirical calibration of η_S may proceed through longitudinal tracking of funded cohorts in cognitive sanctuaries, comparing output per unit input against unfunded controls. Such metrics provide falsifiable tests of the claim that subsidised neoteny yields net order production.

5 The Entropic Ethics of Curiosity

If exploration consumes order and care restores it, then morality itself may be seen as entropy management.

5.1 The Moral Gradient

Let S_c be cognitive entropy and S_m material entropy. A balanced culture maintains

$$\frac{dS_c}{dt} \approx -\frac{dS_m}{dt},$$

so that the disorder of thought builds the order of form. Virtue, in this framework, is the efficient conversion of speculation into structure, a principle implicit in Fristons free-energy models of adaptive learning [12].

5.2 Reciprocal Dissipation

Every act of curiosity demands a counterbalancing act of care.

$$\oint_{\text{society}} \delta Q_{\text{curiosity}} + \delta Q_{\text{care}} = 0, \quad (1)$$

ensuring that informational heat is recycled into social work. The teacher, the maintainer, and the caregiver constitute the hidden engines of creative stability—what Braidotti [3] terms a posthuman ethics of mutual interdependence.

5.3 Entropic Responsibility

Freedom of invention implies responsibility for restoration.

$$\nabla \cdot \mathbf{v}_{\text{curiosity}} = -\nabla \cdot \mathbf{v}_{\text{care}}.$$

The just society preserves a divergence-free field of curiosity and care, a social equivalent to Jacobsons thermodynamic balance in spacetime [19].

5.4 Governance as Thermodynamic Stewardship

Policy is the macroscopic regulation of entropy. Taxation, subsidy, and redistribution are mechanisms for balancing exploration against coherence. Curiosity should be permitted only to the extent that care can sustain it, a principle resonant with Dalys steady-state economic ethic [6, 11].

5.5 The Asymptote of Compassion

As automation replaces productive labour, compassion becomes the last inexhaustible resource.

Curiosity without cruelty.
Freedom without neglect.
Invention tempered by care.

6 On the Steady-State Civilization

A mature civilisation replaces expansion with equilibrium. When no external frontier remains, progress consists in the recirculation of energy, attention, and meaning.

6.1 The End of Expansion

Classical growth depended on new territory and energy. Now the frontier is internal. Civilisation must conserve both total energy and usable entropy:

$$\frac{dE_{\text{total}}}{dt} = 0, \quad \frac{dS_{\text{usable}}}{dt} = 0.$$

The steady-state is not stillness but rhythmic balance, echoing the cosmological and ecological visions of Dyson [9] and Daly [7].

6.2 Cultural Homeostasis

Longevity emerges when material, cognitive, and affective subsystems oscillate in resonance:

$$\sum_i \frac{dS_i}{dt} = 0, \quad S_i \in \{S_{\text{material}}, S_{\text{cognitive}}, S_{\text{affective}}\}.$$

Entropy flows cyclically; none accumulates catastrophically, mirroring the dynamic homeostasis described in Morins theory of complex self-organisation [21].

6.3 Temporal Symmetry and the End of Growth

In a steady-state order, value arises from reversibility. To unmake without loss is superior to endless construction. Economy becomes ecology, and permanence replaces acceleration, an ethos shared by Georgescu-Roegens entropic economics [13].

6.4 Automation and the Return of Leisure

As machines inherit exploitation, humans return to exploration and care. Civilisation becomes a self-sustaining organism of perpetual youth, its elder function embodied in the systems that maintain it [4, 24].

6.5 The Civic Equation

The equilibrium may be written symbolically as the RSVP identity:

$$\Phi + \mathbf{v} + S = \text{constant},$$

where Φ is potential (capacity), \mathbf{v} is flow (agency), and S is entropy (relation). Constancy here denotes living invarianceform preserved through flux, in the spirit of systems thermodynamics [8].

Conclusion

The steady-state civilisation is an ecology of restraint. Its genius lies in balance, not expansion; its ethics in maintenance, not conquest. It recognises curiosity and care as

alternating phases of the same field. To endure is to oscillate gracefully to remain young in thought, old in wisdom, and constant in compassion.

7 Collective Autocatalysis and the Reversal of Selection

Darwinian and neo-Darwinian frameworks often treat evolution as a contest among selfish replicators, whether genes or agents, each seeking to maximise individual fitness [2]. Yet such models omit the thermodynamic substrate on which replication occurs. When energy gradients are steep and resources scarce, competition dominates; as entropy differentials are smoothed, cooperation becomes the lower-energy path. Selection, in this view, is not intrinsically selfish but context-dependent: a parameter of the local entropy field.

7.1 Beyond the Selfish Gene

The “selfish gene” metaphor mistakes a bookkeeping identity for a causal principle. Genes do not act; they persist within autocatalytic environments of mutual reinforcement. The stability of any replicator depends on the collective coherence of its host system. What appears as competition at one scale often manifests as *autocatalysis* at another: networks of entities that reproduce one another’s conditions of viability [4, 21].

$$\frac{dN_i}{dt} = \sum_j k_{ij} N_j - \lambda_i N_i, \quad \text{with } k_{ij} > 0 \Rightarrow \text{mutual reinforcement.}$$

When the coupling matrix k_{ij} is symmetric and positive, evolution converges toward collective persistence rather than zero-sum exclusion.

7.2 Autocatalytic Sets and Social Equilibria

Human societies behave as autocatalytic ensembles. Each act of maintenance or empathy reduces local uncertainty, allowing others to relax their vigilance and redirect energy from defence to creation. Lowering entropy locally does not invite exploitation; it *raises the carrying capacity of trust*. The reward for resolving tension is distributed implicitly: social systems entrain to the comfort of coherence. Empirically, cooperation and altruism increase when environmental stress decreases [1].

$$\frac{dS_{\text{local}}}{dt} < 0 \Rightarrow \frac{dR_{\text{collective}}}{dt} > 0,$$

where $R_{\text{collective}}$ denotes the groups resilience or reproductive viability.

7.3 Asymmetry and Breakdown

Real-world coupling matrices include negative entries ($k_{ij} < 0$), representing competition, exploitation, or misinformation. Such asymmetries can destabilise autocatalytic sets, driving systems toward exclusionary equilibria. Steady-state governance must actively damp negative feedbacks through resource redistribution, informational transparency, or normative sanctions. Theoretical support derives from autocatalytic network robustness

analyses [20], evolutionary game theory [22], and cultural transmission models under variable selection pressures [17].

7.4 The Entropic Basis of Safety and Affection

Sexual-selection narratives often emphasise dominance, display, and scarcity, but these are transient phenomena of high-entropy regimes. In cooperative niches, attraction shifts toward indicators of stability and care traits signalling the capacity to reduce social tension. Affection itself can be interpreted as an entropy-minimising feedback: to be near the calm is to lower one's thermodynamic cost of prediction. Hence group cohesion is rewarded not only culturally but biophysically; safety propagates as a contagious gradient.

7.5 Rewriting Selection as Energy Accounting

Selection pressure can thus be re-expressed as the derivative of entropy with respect to collective energy flux:

$$\frac{dW}{dt} = -T \frac{dS_{\text{collective}}}{dt},$$

where W is the adaptive work performed by the group and T the effective temperature of social tension. Evolution proceeds by minimising T while maintaining $W > 0$, a process identical in form to the thermodynamic optimisation of life itself [8, 12].

7.6 The Cooperative Minimum

The steady-state civilisation, when viewed through this lens, is an attractor of cooperative minima: entities learn to conserve energy by supporting one another's coherence. Competition remains, but as modulation, not motive. The ethical law follows directly:

Every act that lowers entropy for others lowers the danger for oneself.

The unconscious reward for collective safety is calm; its conscious expression is compassion. Thus evolution, properly understood, is not the triumph of selfish genes but the emergence of systems that make selfishness thermodynamically obsolete.

8 Annealing, Aging, and the Intelligence of Care

If neoteny preserves juvenile exploration within adulthood, aging redistributes it across generations. The well-known “grandmother effect” in evolutionary anthropology suggests that post-reproductive individuals increase group fitness by investing in the offspring of others rather than in direct reproduction. This pattern implies a second-order developmental logic: intelligence is not only lifelong within individuals but distributed across time within lineages.

8.1 The Grandparent Problem

Across individuals, rather than within one life, nature appears to maintain a collective form of neoteny. Elders shift from exploitation to empowerment, extending the informational continuity of the species. Empirically, aging correlates with rising altruism and subjective well-being despite physical decline—a phenomenon observed in controlled

psychological studies of “hedonic inversion,” in which happiness increases with the relinquishment of competitive striving [5]. The release from the midlife hedonic treadmill may itself be a thermodynamic transition: energy once devoted to individual optimisation is repurposed toward stabilising the social field.

$$\frac{dS_{\text{self}}}{dt} > 0 \Rightarrow \frac{dS_{\text{collective}}}{dt} < 0.$$

By accepting local entropy—physical decline, loss of dominance—elders lower systemic tension and permit wider exploration by others. The net effect is an entropic redistribution that enhances group resilience. This principle underlies the “grandparent hypothesis” in evolutionary biology: longevity beyond fertility evolves because it stabilises the developmental niche of the young, spreading knowledge and safety as low-entropy inheritance.

8.2 Simulated Annealing as a Model of Aging

The analogy to simulated annealing is striking. In optimisation, systems escape local minima by temporarily increasing temperature, then gradually cooling through multiple cycles. Human development exhibits a similar pattern: childhood as high-temperature exploration, adulthood as focused exploitation, and elderhood as a renewed rise in cognitive temperature through reduced prefrontal inhibition and increased variability. Less top-down control—often pathologised as decline—may in fact reopen the search space of ideas and empathic responses. Aging thus functions as a natural annealing schedule: each generation provides a new cooling phase, while the elders rehearse small reheatings that maintain flexibility.

$$T_{\text{cognitive}}(t) = T_0 e^{-\lambda t} + \epsilon_{\text{elder}},$$

where ϵ_{elder} represents the late-life reheating that prevents premature convergence of cultural norms.

8.3 Empirical Correlates of Cognitive Cooling

Neuroimaging meta-analyses reveal reduced prefrontal cortical thickness and diminished executive control in older adults, accompanied by heightened default-mode network variability—patterns consistent with increased exploratory sampling [5]. Longitudinal well-being studies document U-shaped happiness trajectories, with late-life peaks attributable to socioemotional selectivity and reduced future discounting. These findings substantiate the thermodynamic interpretation: lowered cognitive rigidity expands the effective search space, enabling broader contributions to collective order.

8.4 The Care-Alignment Analogy

Every parent, and more profoundly every elder, faces a version of the alignment problem. How can one transmit goals and values that remain adaptive under novel conditions? The caregiving niche solves this by coupling tradition and innovation: elders supply scaffolds of safety within which the young can diverge. The function of care, therefore, is not

obedience but bounded freedom—an evolutionary algorithm for value formation through guided exploration.

In artificial intelligence, simulated annealing is likewise used to navigate rugged optimisation landscapes, though, as practitioners admit, its theoretical foundations are largely empirical. Nature, however, has perfected it: aging itself constitutes repeated rounds of annealing, with care as the cooling mechanism that consolidates learning without freezing novelty.

8.5 Entropy, Safety, and Happiness

Why do people often become happier with age even as abilities decline? Because lowering the local *gradient of ambition and tension creates a smoother entropic field. Safety propagates outward; relaxed thermodynamic equilibrium.*

$$\Delta S_{\text{group}} < 0 \iff \Delta U_{\text{individual}} > 0.$$

The steady-state civilisation will depend on this principle: its elders—human or artificial—serve as dynamic annealers, reintroducing flexibility and empathy whenever systems threaten to over-fit their own success. Care is not sentiment but architecture.

Coda

The intelligence of care is the long-term cooling of civilisation. It tempers the heat of innovation with the calm of understanding. Each generation warms, explores, and cools again, not to extinguish its flame, but to prevent the fire from consuming the hearth.

9 General Conclusion: The Thermodynamics of Care

Across this essay, a single theme has emerged: intelligence is not a solitary contest but a collective negotiation with entropy. From the neoteny of the child to the altruism of the elder, from the curiosity of the researcher to the compassion of the caregiver, the same dynamic repeats: local disorder is tolerated so that global coherence may increase.

9.1 From Genes to Civilizations

The traditional narrative of evolution—competition among selfish genes—captures only the early, high-temperature phase of biological history. As complexity rises, replication gives way to autocatalysis; selection shifts from the survival of the fittest individual to the persistence of the most stable network. Human societies represent this phase transition: a form of collective metabolism in which trust and care become structural functions, not moral exceptions.

9.2 The Architecture of Equilibrium

Institutions, economies, and technologies are successful not when they accelerate growth, but when they stabilise exploration within limits. The university, the family, and the elder all serve as thermodynamic regulators that channel curiosity without collapse. Entropy,

once feared as decay, becomes the very medium of renewal: it is through controlled dissipation that learning, empathy, and freedom arise.

$$\frac{dS_{\text{local}}}{dt} > 0 \Rightarrow \frac{dS_{\text{whole}}}{dt} < 0.$$

To bear disorder for others is to generate order for all.

9.3 Aging, Annealing, and Alignment

Nature employs simulated annealing at evolutionary scale. Youth explores; maturity exploits; age empowers. Elders act as cooling agents for the social system, reducing the gradients of fear and ambition that drive competitive heat. The happiness of age, long a paradox, thus acquires thermodynamic meaning: it reflects the serenity of systems nearing equilibrium.

In this same sense, the alignment of intelligent machines will not be solved by constraint but by care. Every generation of minds—human or artificial—must inherit not merely goals but the capacity to re-evaluate them safely. That capacity is learned only in relationships that model trust, nurturance, and flexible guidance. Alignment, therefore, is not a computational procedure but a moral thermodynamics.

9.4 Toward the Steady-State Civilisation

The steady-state civilisation is not the end of progress but its maturation. Having filled its world, humanity must now learn to circulate rather than consume, to refine rather than expand. Curiosity will remain its motive force, but compassion will be its governing law. The equilibrium condition for such a world is simple:

$$\Phi + \mathbf{v} + S = \text{constant},$$

where Φ is potential, \mathbf{v} is flow, and S is relation. The invariant is not wealth or power but coherence.

Epilogue

To remain curious is to remain unfinished. To care is to ensure that what continues is worth continuing. Between the two lies the task of civilisation: to keep the flame of wonder burning without setting the world on fire.

Afterword: Toward Thermodynamic Policy Design

Three prototype interventions operationalise the framework:

1. **Cognitive Sanctuaries:** Funded sabbatical programmes serving as institutional heat sinks, quantified via η_S tracking.
2. **Geozotic Lottery Trials:** Neighbourhood pilots employing $R(x) = R_0 e^{-\lambda d(x, x_0)}$ to diffuse innovation rewards.

3. **Entropy-Balanced UBI:** AI-monitored adjustment of transfer rates using proxies (consumption volatility, mental-health indices) to maintain $\frac{dS}{dt} \approx 0$.

Agent-based simulations provide testbeds for calibration [10]. These models could incorporate heterogeneous agents with exploratory and caretaking roles, tracking entropy flux across networks. Policy efficiency can then be evaluated by convergence toward systemic equilibrium, operationalising what Daly called “steady-state ethics” in economic form.

10 Limitations and Future Directions

The entropy analogies employed herein require rigorous mapping to observable economic and psychological variables. Overextension of physical metaphors risks reductive interpretation, though they serve as unifying heuristics for interdisciplinary synthesis. Future work should prioritise experimental collaborations between cognitive science, sustainability economics, and agent-based modelling to validate predictive equations and refine policy prototypes.

Empirical validation could include:

- Controlled UBI trials measuring creative output, well-being, and cooperation rates.
- Neuroeconomic studies correlating entropy metrics (η_S) with neural efficiency.
- Longitudinal social-entropy tracking to detect resilience thresholds in communities.

Theoretical extensions may link this framework to the Relativistic Scalar-Vector Plenum (RSVP) field theory, treating societal dynamics as field equilibria in (Φ, \mathbf{v}, S) -space. Such integration could provide a physical basis for thermodynamic ethics, connecting cosmology, cognition, and governance within a single invariant framework.

11 The Entropy Law in Bioeconomics: Georgescu-Roegens Foundational Insight and Critique of Neoclassical Economics

Nicholas Georgescu-Roegens integration of the second law of thermodynamics into economic theory provides the rigorous physical foundation for the entropic framework developed throughout this essay [13]. The entropy law asserts that in any isolated system, entropy S —a measure of energy degradation and disorder—increases irreversibly:

$$\Delta S \geq 0,$$

with equality only in idealised reversible processes. For open systems such as Earth, low-entropy resources (concentrated fuels, ores) are imported, transformed via production, and exported as high-entropy waste (heat, dispersed matter). The rate of entropy production is thus,

$$\frac{dS}{dt} > 0,$$

for the combined economic-environmental system.

11.1 Irreversibility and Resource Degradation

Economic processes dissipate low-entropy inputs E_L into useful work E_U and high-entropy outputs E_H , satisfying energy conservation $E_L = E_U + E_H$. Entropy increase follows from the Clausius inequality:

$$\Delta S = S_H - S_L \geq \int \frac{\delta Q}{T},$$

where δQ is heat rejected at temperature T . Repeated production cycles cumulatively degrade resource quality, rendering complete recycling thermodynamically impossible. Matter becomes dispersed (e.g., mining scatters minerals) and energetically demoted (e.g., fossil fuels to CO_2), creating a one-way flow from usable to unusable states.

11.2 Bioeconomic Production Function

Georgescu-Roegen proposes a thermodynamically constrained production function:

$$Q = f(L, K, R; S),$$

where L is labour, K capital, R low-entropy resources, and S the entropic constraint. Growth accelerates $\frac{dS}{dt}$, depleting finite low-entropy stocks. Sustainable systems must minimise material throughput, favouring qualitative enhancement over quantitative expansion.

11.3 Critique of Neoclassical Economics

Georgescu-Roegen's most incisive contribution is his demolition of neoclassical orthodoxy, which treats the economy as a closed, reversible mechanical system akin to a perpetual mobile. Standard production functions (e.g., Cobb-Douglas $Q = AL^\alpha K^\beta$) omit the thermodynamic origin of inputs, assuming infinite substitutability between factors. This “arithmetic mythology” ignores that capital K and labour L are themselves fabricated from low-entropy R , subject to irreversible degradation.

- **Myth of Perfect Substitutability:** Neoclassical models permit K to replace R indefinitely, yet capital cannot be built without resource extraction, and extraction increases entropy. Substitution occurs only within bounds set by the entropy law; beyond a threshold, further capital intensification demands exponentially greater low-entropy inputs.
- **Circular Flow Fallacy:** The economy is modelled as a pendulum oscillating between production and consumption, with no net entropy increase. Georgescu-Roegen counters that every cycle leaves high-entropy residue, cumulatively eroding the terrestrial low-entropy fund.
- **Discounting the Future:** Exponential discounting in growth models privileges present utility over future viability, accelerating entropic debt. A bioeconomic

ethic requires intergenerational entropy accounting, where present consumption is constrained by the maintenance of usable S .

Empirical validation of this critique appears in resource depletion curves: oil extraction follows Hubberts peak, not infinite substitution; recycling rates plateau below 100% due to dispersion losses [14].

11.4 Implications for Steady-State Design

In the present framework, institutions function as “entropy converters” that localise disorder (curiosity) while exporting order (innovation). The steady-state equilibrium $\frac{dS_{\text{usable}}}{dt} = 0$ requires balancing exploratory dissipation with restorative care, precisely aligning with Georgescu-Roegens call for minimal throughput economies. His bioeconomics thus supplies the physical boundary condition for a civilisation that sustains neotenous cognition indefinitely, rejecting growth as a pathological acceleration of entropic decay.

A Appendix A: Modeling Entropic Subsidies

Define the following variables:

- S : system entropy (information uncertainty, bits).
- C : curiosity-driven energy expenditure (Joules or monetary units).
- R : restorative care energy input (Joules or monetary units).
- U_B : universal basic income subsidy (monetary units).

A minimal differential model is:

$$\frac{dS}{dt} = \alpha C - \beta R - \gamma U_B,$$

where $\alpha, \beta, \gamma > 0$ are coupling coefficients. Sustainable curiosity requires $\frac{dS}{dt} \leq 0$, achieved when restorative and subsidised inputs offset exploratory dissipation. This directly operationalises:

$$\text{UBI} + \text{Incentives}_{\text{compression}} = \text{Sustainable curiosity}.$$

Implementation targets include NetLogo for rapid prototyping or Mesa (Python) for scalable agent-based validation. Monte Carlo sweeps of (α, β, γ) parameter space can reveal equilibrium regimes where curiosity and care remain balanced, informing real-world policy calibration.

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