Bridging the Gap: How Goals Emerge from a Purposeless Universe

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Abstract

The Fundamental Puzzle

Fundamental physics describes dynamics without ends, yet biology and cognition teem with goal-directed talk. How can we reconcile these perspectives?

Proposed Synthesis: *Goals* are emergent, graded organisational phenomena arising when far-from-equilibrium systems:

- Acquire reliable, history-dependent information about their environment
- Couple that information to control architectures that maintain their own viability

Introduction: The Central Puzzle

Physics Perspective:

- Laws indifferent to ends
- Dynamics without teleology
- Purposeless microphysics

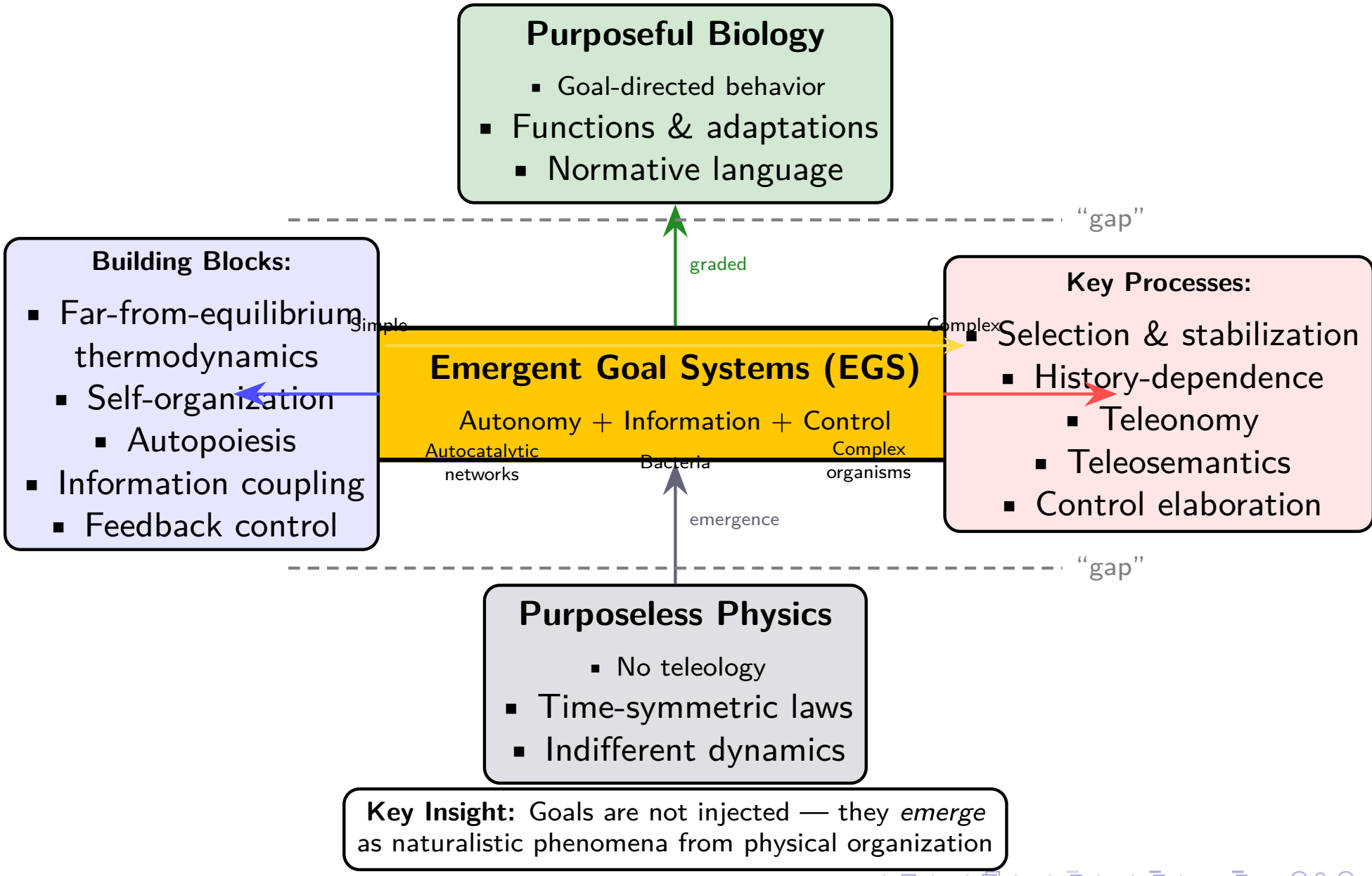
Biology Perspective:

- Cells "seek" nutrients
- Organisms "repair" damage
- Populations "adapt"
- Goal-filled macrodynamics

Research Questions:

1. What minimal features distinguish genuine goal-directedness from metaphor?
2. How do such features arise from nonliving matter?

Goals from purposeless physics?



Key definitions

Teleology Explanations in terms of purposes or for-the-sake-of (e.g. "the heart exists to pump blood").

Teleonomy A naturalistic, historical account: apparent purposefulness of traits arises from selection histories; functions are etiological.

Teleosemantics Extension of the etiological logic to representation: internal states *mean* what they do because of evolutionary/selection histories that linked those states to adaptive success.

Synthesis

1. *Teleonomy explains why biological structures are functionally organised (selection histories); teleosemantics explains why internal states can be said to* represent *the world (selection confers semantic roles).*
2. *Teleonomy refers to the naturalistic project of explaining the apparent purposiveness of biological traits by their selection histories, while teleosemantics extends this etiological logic to representations, holding that the semantic content of internal states is grounded in evolutionary histories that linked those states to adaptive success.*

Synthesis

Helpful examples

1. Heart: teleonomic explanation — hearts were selected because pumping blood improved survival; we can validly say "the heart is for pumping blood."
2. Bacterial chemotaxis: the signalling state that triggers tumbling vs. running has teleosemantic content ("nutrient gradient increasing" vs "decreasing") because selection linked those signalling states to adaptive movement.

Synthesis

- Far-from-equilibrium systems + information + control $\Rightarrow$ goal-like organisation.

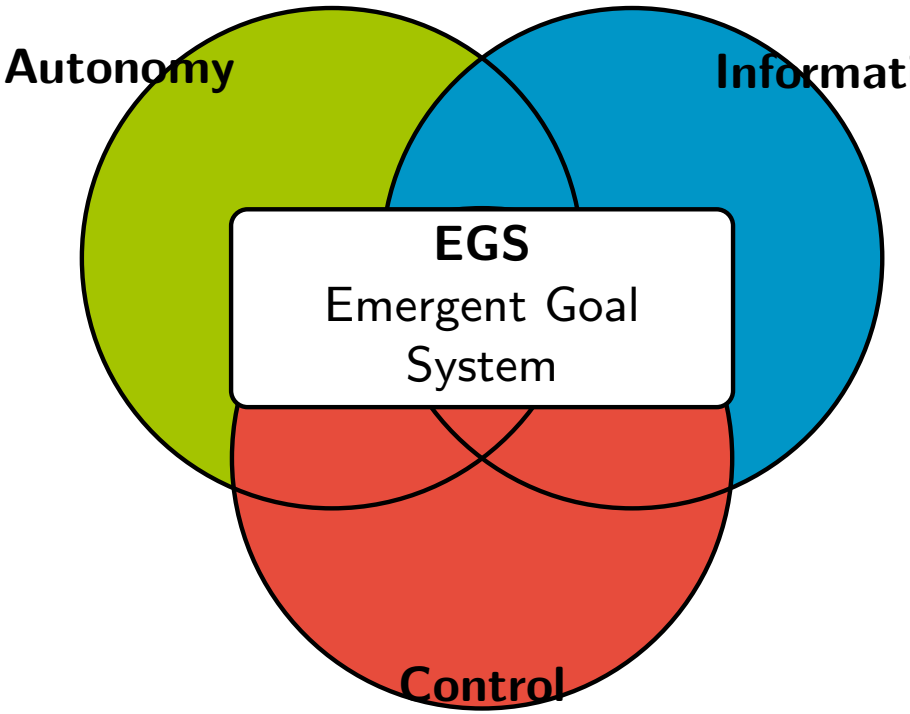
Emergent Goal Systems (EGS): Core Definition

EGS: Physical systems satisfying three joint conditions:

1. **Autonomy / Self-Maintenance**
   - Maintains bounded set of internal relations
   - Constitutes identity over relevant timescales
   - Defines a viability domain
2. **Information-Bearing Coupling**
   - Acquires and stores environmental regularities
   - Information causally informs persistence
3. **Control/Use of Information**
   - Uses information in feedback loops
   - Reduces probability of exiting viability set

Key Insight: Goals are *emergent*, *graded phenomena* — nothing metaphysical is added.

The EGS Framework: Visual Representation



Complex animals

Bacteria

Chemical networks

Graded Nature of EGS:

- Minimal autocatalytic networks → Proto-level goals
- Bacteria with homeostasis → Intermediate level
- Complex animals with hierarchical control → High level

From Nonliving Matter to EGS: Causal Pathways

1. Self-Organization under Constraints

Chemical/physical gradients drive pattern formation. Persistent structures serve as substrates for complex organization.

2. Embedding of Information

Repeated interactions create correlations. Chemical/structural memory encodes useful environmental information.

3. Selection and Stabilization

Variants that resist perturbation persist. Selection amplifies viability-preserving mechanisms (teleonomic bias).

4. Control Architecture Elaboration

Hierarchical feedback and state-dependent switching enable anticipatory behaviour. Increases adaptability and response repertoire.

Operational Markers for Goal-Directedness

To avoid mere metaphor, test for:

1. **Viability Set Identification**
   Can we define conditions whose maintenance corresponds to persistence?
2. **Information-Viability Coupling**
   Measurable mutual information between internal states and environmental variables predictive of viability loss?
3. **Control Efficacy**
   Do interventions on control loops modulate probability of exiting viability set?
4. **Heritability/Evolvability**
   Do maintenance structures show variation and differential persistence under selection?

Test Outcome

If yes $\rightarrow$ Treating system as goal-directed yields explanatory and predictive benefits.

Illustrative Examples Across Complexity Scales

Autocatalytic Networks

Proto-Goals:

- Persist and reproduce under fluxes
- Encode environmental regularities
- "Respond" to sustain themselves
- (6)

Single-Celled Organisms

Clear EGS:

- Maintain homeostasis
- Sense gradients, enact chemotaxis
- Satisfy all three EGS conditions
- Modest complexity level

Animal Nervous Systems

High-Grade EGS:

- Hierarchical control architectures
- Homeostasis, appetitive circuits, planning
- Flexible, predictive action
- Complex information-control coupling

Moral consideration for hybrots & synthbiosis

- **Graded view:** moral consideration tracks degree of goal-directedness (not a binary).
- **Distinct goal-types:** (i) instrumental/designed; (ii) homeostatic/viability-preserving; (iii) emergent/history-dependent.
- **Ethical marker:** moral standing is more plausibly tied to capacities for welfare, vulnerability, and morally salient interests — features of high-grade EGSs.
- **Practical implications:** adopt graded protections and regulatory oversight; require precautionary design, transparency about biological integration, and protocols to assess autonomy, valence, and dependence.

Takeaway: as hybrid systems acquire deeper autonomy (7) and richer information–control coupling, ethical weight and obligations on designers/deployers increase.

Open Questions for Future Research

Theoretical Frontiers

- **Cross-Level Responsibility:** How should moral/legal frameworks apportion responsibility across EGS levels (cells $\rightarrow$ organisms $\rightarrow$ collectives $\rightarrow$ institutions)?
- **What other minds exist and what goals might they have?**

Conclusion: Bridging the Gap

The Synthesis:

- Purposeless microphysics $\rightarrow$ Goal-filled biosphere
- Not metaphysical abyss but explanatory bridge
- Far-from-equilibrium physics enables persistent organization
- Autopoietic autonomy provides stakes
- Information-viability coupling + feedback control realize action
- Selection stabilizes and amplifies capacities

Core Contribution:

- Goals as *naturalistic phenomena*
- Emergent products of history and organization
- No injection of purpose into nature required

Ten Oxherding Pictures: a way to think about goals

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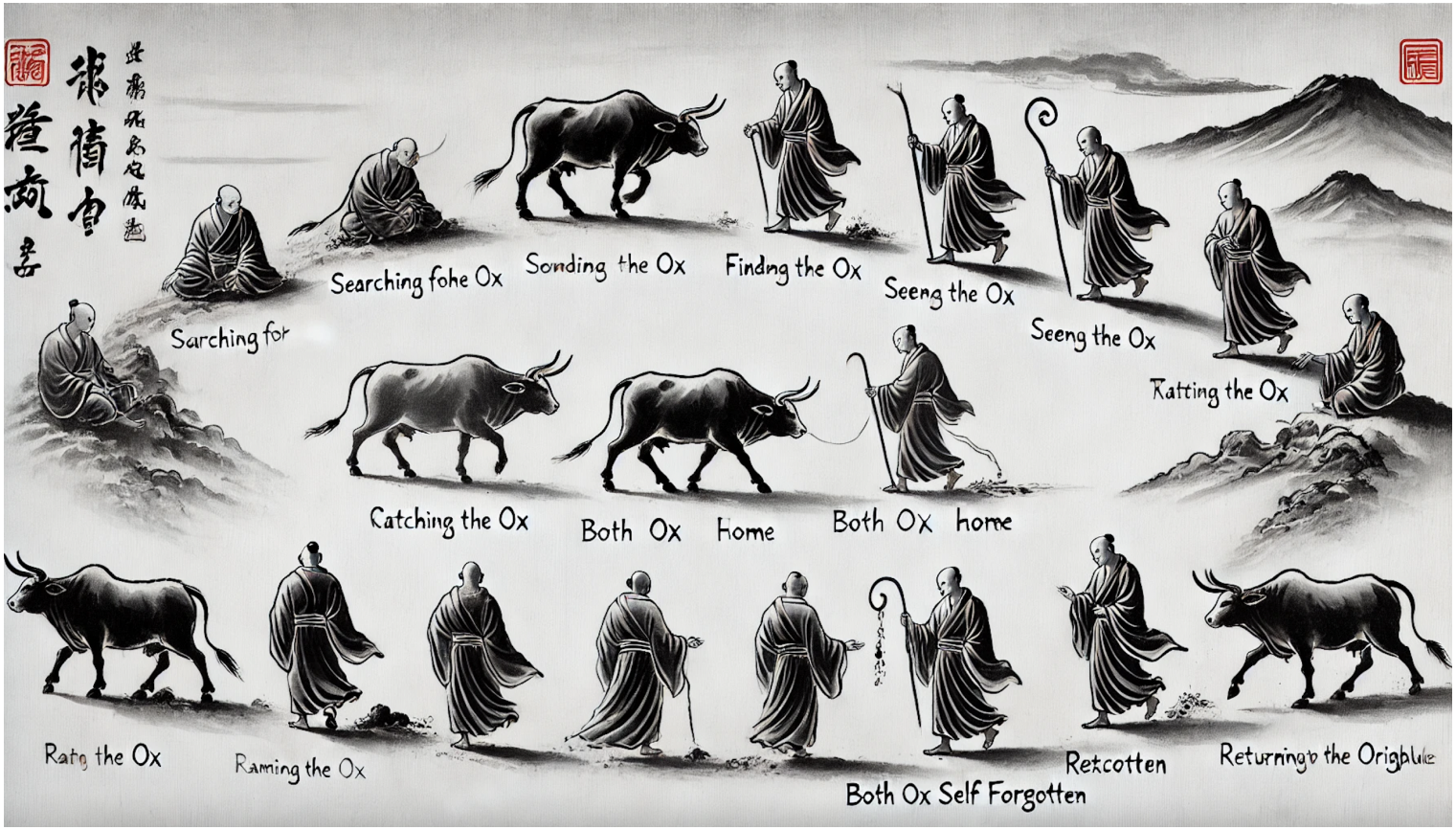

Stages 1–4: notice, detect, recognise, harness

1. **Searching for the Ox** — surprise at persistent regularities.
2. **Perceiving the Ox** — an emergent attractor coheres and we label it a ‘goal’ as an explanatory shorthand.

Stages 5–8: internalise, embody, transcend

5. **Both Ox and Self Transcended** — nondual view: seeker and sought are phenomena within the same organized process.

Stages 9–10 and closing reflections

Reflections

- Later ox pictures dissolve the boundary: goals often become *patterns embodied in agents*, not external mandates.
- Object-process dichotomy.
- Goal and seeker become one.

"Like the herder who ultimately and gently becomes one with the ox, perhaps our purposes arise from the very processes we once called purposeless.

More questions, fewer answers

References

[1] Schrödinger, E. (1944). *What Is Life?* Cambridge University Press.

[2] Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and Cognition*. D. Reidel.

[3] Millikan, R. G. (1984). *Language, Thought, and Other Biological Categories*. MIT Press.

[4] Godfrey-Smith, P. (2009). *Darwinian Populations and Natural Selection*. Oxford University Press.

[5] Friston, K. (2010). The free-energy principle. *Nature Reviews Neuroscience*, 11(2), 127-138.

[6] Kauffman, S. A. (2016). Autocatalytic sets and the origin of life. *Journal of Theoretical Biology*, 389, 1-9.

[7] Michael Levin, "Artificial Intelligences: A Bridge Toward Diverse Intelligence and Humanity's Future," *Advanced Intelligent Systems*, 2025, Art. no. 2401034. doi:10.1002/aisy.202401034. Available: `https://onlinelibrary.wiley.com/doi/10.1002/aisy.202401034`.

Thank You

Questions?

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