The Principle of Optimal Coherence

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Abstract

This article proposes the Principle of Optimal Coherence as a methodological tool for scientific investigation. The principle states that in any system where a fixed and non-contradictory set of constraints fully determines an admissible set of probable configurations, the realized configuration is one for which no alternative admissible configuration can achieve higher global coherence without violating at least one constraint. Drawing on recent developments in constraint-based accounts of laws of nature, the Law of Scale-Specific Principles, variational principles in physics, and Leibniz's concept of compossibility, the article argues that this principle provides a productive heuristic for research: when encountering apparently anomalous or suboptimal features in a coherent system, the investigator should assume structural necessity and seek the constraints that the feature ensures.

1 Introduction

In the traditional "Newtonian" paradigm of science, the investigation of systems has been dominated by the dynamical time-evolution perspective. In this view, laws are recipes that compute future states from the past, and any element of a system that does not fit a direct causal chain is often labeled an "anomaly," "noise," or a "suboptimal accident." This "dynamical chauvinism" (Adlam, 2022) has led researchers to treat the "strangeness" of certain configurations as a defect of the system rather than a defect of our understanding.

However, contemporary physics—from General Relativity to Quantum Foundations—is undergoing a fundamental shift toward Constraint-Based Accounts of Laws (Adlam, 2022; Chen & Goldstein, 2022; Meacham, 2025). In this emerging paradigm, laws do not "produce" events; they function as global, atemporal constraints that delimit the space of physical possibilities. They operate "all-at-once" on the entire history of a system, ensuring its structural integrity and coherence.

If laws are indeed global constraints, then the very notion of "suboptimality" or "contingency" within a stable system must be re-evaluated. If a system exists and persists, it must, by definition, satisfy the conditions of its own coherence. Therefore, what an investigator perceives as a “strange” or “redundant” element is likely a load-bearing constraint—a necessary structural requirement that ensures the system does not “fall apart” into a state of decoherence or logical contradiction.

This article proposes the Principle of Optimal Coherence not as an ontological claim about the “best of all worlds,” but as a rigorous epistemological tool. Building on the “minimal primitivism” of Chen and Goldstein and the “explanations by constraint” of Marc Lange (2023), this principle directs the investigator to treat the hypothesis of structural necessity as the only productive starting point for inquiry.

By reframing “possible alternatives” as logical fictions—configurations that the system’s constraint structure simply does not accommodate—the Principle of Optimal Coherence provides a bridge between the abstract metaphysics of constraints and the practical demands of scientific investigation. It transforms the “apparent strangeness” of a phenomenon into a diagnostic signal, pointing the researcher toward the fundamental load-bearing structures of reality.

2 Formulation of the Principle

The Principle of Optimal Coherence: It should be assumed that in any system where a fixed and non-contradictory set of constraints fully determines an admissible set of probable configurations, the realized configuration is one for which no alternative admissible configuration can achieve higher global coherence without violating at least one constraint.

Several consequences follow from this principle. First, the principle concerns the optimality of the system as a whole, not of every individual element within it. A system may contain vestigial, redundant, or apparently suboptimal components; the principle does not deny this. Second, if a configuration appears arbitrary, redundant, or suboptimal, this indicates an incomplete understanding of the constraints that ensure coherence. Third, the principle is not an ontological claim about the nature of reality but an epistemological tool—a direction of the investigator’s attention that increases the efficiency of inquiry.

3 The Load-Bearing Column Metaphor

Imagine an architect examining an old building. In the middle of a spacious hall, she discovers a column that seems out of place—it breaks the symmetry, obstructs movement, spoils the view. The first reaction: this is a design error; it should be removed. However, an experienced architect knows: before declaring an element redundant, one must check whether it is load-bearing. The column may carry a critical load without which the building would collapse.

The principle of optimal coherence transfers this logic to the investigation of any system: when encountering something that appears strange or suboptimal, assume it is a constraint ensuring the system's coherence. Seek what it "holds up."

4 Examples Across Disciplines

4.1 Physical Constants and Fine-Tuning

Modern physics reveals that fundamental constants (the fine-structure constant, the cosmological constant, the ratio of particle masses, etc.) lie within an extremely narrow range compatible with the existence of complex structures—atoms, stars, galaxies, life. This is often called "fine-tuning." We can treat this not as a problem requiring explanation but as a demonstration of the principle: if the universe is coherent, then its parameters must satisfy conditions of coherence, just as a flying airplane's center of gravity must be within certain tolerances.

4.2 Consistency of Mathematical Systems

The axioms of arithmetic or set theory are not "arbitrary rules of the game" but conditions ensuring the coherence of the entire mathematical system. If we remove or alter one of them, the system may become contradictory or lose its structure. Gödel's theorem shows that within any sufficiently powerful system there exist true statements that cannot be proven within the system—this is also a constraint ensuring coherence.

4.3 Stability of Economic Systems

In a market economy, prices, interest rates, supply and demand relationships, and property rights form a system of constraints. If the system functions stably (does not collapse into hyperinflation, deflation, or barter), its parameters must be in a state ensuring coherence. A seemingly "unjust" price may be the only point at which supply equals demand given all other constraints.

4.4 Biological Coherence

Organisms are systems with constraints operating at many levels—genetic, biochemical, physiological, ecological. The stability of an organism implies that its parameters satisfy all these constraints simultaneously. A seemingly "suboptimal" organ may be the only solution compatible with a multitude of other constraints.

5 Related Work in Contemporary Philosophy of Science

5.1 Constraint-Based Accounts of Laws

Recent work by Adlam (2022), Chen & Goldstein (2022), and Meacham (2025) has developed accounts of laws of nature as primitive global constraints rather than causal or dynamical processes. On these views, laws govern by constraining physical possibilities atemporally and "all-at-once," rather than by producing later states from earlier ones.

Chen and Goldstein's Minimal Primitivism (MinP) deserves particular attention. They argue that fundamental laws are primitive facts that govern by constraining physical possibilities rather than by dynamically producing later states from earlier ones. On their account, laws need not presuppose a fundamental direction of time; they can constrain entire spacetimes "all-at-once." As they put it: "Laws govern by constraining the physical possibilities." This ontological picture provides direct support for the present principle. If laws are global constraints that delimit the space of coherent configurations, then the question "why this configuration and not another?" dissolves: alternative configurations are not ontologically real options that were excluded by selection, but logical fictions that the constraint structure simply does not accommodate. The principle of optimal coherence can thus be understood as the methodological counterpart to MinP: where Chen and Goldstein describe what laws are (primitive constraints), the present principle describes how investigators should approach systems governed by such laws—by seeking the constraints that ensure coherence rather than the mechanisms that produced outcomes.

Adlam develops this framework further. She argues that the traditional "dynamical paradigm"—the assumption that laws must take the form of time-evolution equations that compute later states from earlier ones—constitutes an unwarranted constraint on scientific theorizing. This "dynamical chauvinism" has become deeply embedded in both physics and philosophy of science, yet it conflicts with developments in quantum mechanics, general relativity, and quantum gravity where non-dynamical, global, or retrocausal laws play increasingly important roles.

Adlam proposes that laws should be understood in terms of modal structure—specifically, as constraints that delimit which configurations (or "Humean mosaics") are possible. Formally, a constraint is defined as a set of Humean mosaics, and a law requires that the actual mosaic belong to this set. This framework accommodates laws that apply "all-at-once" to entire histories rather than moment by moment, including Lagrangian optimization principles, consistency conditions, and information-theoretic constraints like the no-signalling principle.

Importantly, Adlam's framework offers a novel approach to the fine-tuning problem: if laws are global constraints on the space of possible configurations, then what appears to be improbable coincidence in a time-evolution picture may become logically necessary consequence of global structural requirements. Configurations violating these constraints simply do not constitute coherent physical systems—they are not genuine alternatives from which our world was "selected."

Meacham (2025) has provided a systematic analysis of what he terms "Primitive Global Constraint accounts," examining the proposals of Adlam, Chen and Goldstein, and his own earlier work. He identifies three defining features shared by these accounts: (i) they posit primitive nomic features of the world, (ii) these features are global—operating at the level of the world as a whole rather than locally, and (iii) while these features constrain what the world must be like, they do not engage in substantive time-asymmetric relations such as production or generation. Crucially, Meacham demonstrates that constraint accounts can accommodate the full variety of laws that physicists take seriously—including initial condition laws, conservation laws, functional laws, retrocausal laws, and laws whose solutions are complete histories—whereas traditional accounts (Humean, Necessitation Relation, Dispositional Essentialist, and Primitive Local Dynamics) all face significant difficulties with one or more of these categories.

5.2 The Law of Scale-Specific Principles

The structural necessity identified by the Principle of Optimal Coherence receives further mathematical support from the Law of Scale-Specific Principles, formulated and established by Kriger (2024). The law states that whenever extrapolation between physical scales fails while stable observables persist, the mathematical framework of renormalization and effective field theory requires the introduction of scale-specific governing principles. The proof, carried out within standard effective field theory and renormalization-group formalism, employs operator relevance, stability arguments, and genericity constraints to show that failed extrapolation cannot be coherently resolved without introducing new organizing structures at the new scale.

This result provides a formal basis for the Principle of Optimal Coherence: the "new organizing structures" required at each scale are precisely the constraints that ensure the system's coherence at that scale. If a system exhibits stable observables, yet its behavior cannot be derived from lower-scale laws, then scale-specific principles are not optional theoretical conveniences but mathematical necessities. The "load-bearing columns" sought by the present principle are thus the concrete instantiations of what renormalization-group analysis shows must exist. In the present work, this law is treated as an established result and is used as an operative constraint to advance the analysis.

5.3 Explanations by Constraint

Lange (2017) has developed the notion of "explanation by constraint" as a form of non-causal scientific explanation. Such explanations work by showing that certain facts are constrained to be as they are—not by causal processes, but by principles that make them "more necessary than the ordinary laws of nature." Conservation laws, symmetry principles, and mathematical necessities can all function as explanatory constraints. Lange's work demonstrates that constraints can be genuinely explanatory without invoking causal mechanisms.

Crucially, Lange (2023) has extended this analysis beyond physics to show that explanations by constraint operate in the human sciences as well. Using linguistics as his primary example, he demonstrates that certain facts about kinship categorization systems are explained not by the causal processes of language change but by structural constraints that delimit what is possible for any human language. This extension is directly relevant to the present proposal: if explanations by constraint operate across physical, biological, and human sciences, then a methodological principle oriented toward finding such constraints—the principle of optimal coherence—has genuinely universal scope.

5.4 Variational Principles and Modal Metaphysics

The principle of least action and related variational principles in physics describe physical evolution as the extremization of some quantity (typically action) subject to constraints such as boundary conditions. Philosophers including Butterfield (2004), Terekhovich (2018), and Glick (2023) have examined the modal and metaphysical implications of these principles.

Terekhovich's modal interpretation of the principle of least action is particularly illuminating for the present proposal. Drawing on Leibniz's concept of essences striving for existence, Terekhovich argues that possible histories in the principle of least action possess a kind of reality in what he calls the "possible modality of being." On his interpretation, all possible paths "compete" for actualization, but only the path with minimal action—which Terekhovich identifies as having the "highest degree of essence"—achieves actual existence. The action, in this framework, becomes a physical measure of the essence or "degree of reality" of each possible history.

This metaphysical picture provides direct support for the principle of optimal coherence. What appears as mysterious "selection" of the optimal path is reframed as a natural consequence of the structure of possibility itself: configurations with insufficient coherence (higher action) simply lack the "degree of essence" required for actualization. They do not fail to be selected from a pre-existing set of alternatives; rather, they fail to achieve the threshold of reality. The "multitude of alternatives" exists only in the possible modality, not as genuine competitors in actuality.

The connection to Feynman's path-integral formulation deepens this analysis. In the path-integral picture, a quantum system "explores" all possible paths simultaneously, but only those paths whose phases are coherent contribute to the final amplitude—incoherent paths cancel through destructive interference. As Terekhovich notes, the classical limit emerges when the bundle of contributing paths shrinks to the single world-line of minimal action. This is a precise physical instantiation of the idea that only coherent configurations are realized: coherence (phase alignment) determines which possibilities achieve actuality.

Glick (2023) reinforces this picture. He argues that the principle of least action functions as a diachronic constraint—a requirement on the total evolution of a system from initial to final state—rather than as a teleological principle invoking final causes. PLA-based explanations are non-causal: they do not appeal to earlier causes producing later effects, but to global features that the entire trajectory must satisfy.

5.5 Effective Complexity and Edge of Chaos

Gell-Mann (1994) and Gell-Mann & Lloyd (1996) introduced the concept of effective complexity as the length of a highly compressed description of a system's regularities, distinguishing it from both total information and random noise. Langton (1990) explored the "edge of chaos" hypothesis, suggesting that complex adaptive systems tend to operate at a critical boundary between order and disorder. These frameworks provide quantitative tools for understanding what "coherence" might mean: a system is coherent when it exhibits rich, compressible patterns (high effective complexity) rather than mere randomness or rigid order.

6 Novelty of the Present Approach

Several features distinguish this proposal from related work.

Scope and generality. The principle is formulated without restriction to any particular domain. The constraint-based accounts of Adlam, Chen and Goldstein, and Meacham focus primarily on physics. Lange's explanations by constraint have been extended to linguistics but remain focused on identifying specific constraints in particular domains. The principle of optimal coherence is a domain-general methodological directive applicable wherever coherent systems are investigated.

Epistemological rather than ontological status. Unlike the ontological claims of constraint-based accounts of laws, the principle of optimal coherence is offered as a methodological heuristic. It does not assert that laws *are* constraints in any metaphysical sense; it asserts that *treating* observed configurations as constraint-satisfying is a productive investigative strategy. This epistemic modesty makes the principle applicable even where the underlying metaphysics of laws remains disputed. At the same time, the principle is complementary to these ontological accounts: Chen & Goldstein (2022) provide the ontology (laws as primitive constraints), while the principle of optimal coherence provides the methodology (seek coherence conditions rather than causal mechanisms).

The diagnostic role of anomaly. Other approaches treat constraints as explanatory resources to be deployed once identified. The principle of optimal coherence goes further by providing a systematic research strategy: apparent anomalies, redundancies, or suboptimalities are not obstacles to understanding but diagnostic signals pointing toward unrecognized constraints. This inverts the typical explanatory direction: instead of asking "why does this anomaly exist?" the principle directs us to ask "what coherence does this apparent anomaly ensure?"

7 Limits of Applicability

The principle applies within the domain of coherent systems. It does not assert that all systems are coherent, nor does it provide criteria for determining whether a given system is coherent. Its applicability is limited to systems that demonstrate stable, persistent, organized behavior—a judgment that must be made prior to applying the principle.

The principle does not assert that every element of a system is necessary. It asserts that the *assumption* of necessity is a productive research strategy. After exhausting coherence-based explanations, an element may legitimately be classified as vestigial, accidental, or genuinely arbitrary. The principle is a heuristic, not a metaphysical thesis.

8 Relationship to Falsificationism

Karl Popper's falsificationism demands that scientific hypotheses be testable through potential refutation. The principle of optimal coherence is compatible with this requirement. The hypothesis "element X ensures coherence condition Y" is falsifiable: if removing or altering X does not compromise Y, the hypothesis is refuted. The principle does not immunize any particular claim from refutation; it merely directs the investigator to formulate coherence-based hypotheses rather than dismissing anomalies as noise.

9 Teleology as Epistemological Tool

Teleological reasoning—explaining phenomena by reference to purposes, goals, or ends—has been largely excluded from natural science since the Scientific Revolution. Bacon, Descartes, and their successors argued that final causes have no place in physics; explanation must proceed through efficient causes alone. This rejection was well-founded as an *ontological* claim: there is no evidence that natural systems are guided by purposes or that future states exert causal influence on present ones. Teleology as metaphysics is not admissible in scientific explanation.

However, the exclusion of teleology as ontology does not entail its exclusion as *methodology*. There is a crucial distinction between claiming that a system *has* a purpose and using purposive reasoning as a heuristic tool for *understanding* the system. The latter is epistemologically innocent and, we argue, highly productive.

The reason is straightforward: human beings are teleological creatures. We are goal-directed agents who design artifacts, make plans, and act for reasons. Our cognitive architecture is optimized for understanding purposive systems—we naturally ask “what is this for?” and “how would I achieve this goal?” This is not a defect to be overcome but a resource to be exploited. When investigating a coherent system, the question “how would I design a system to achieve this outcome?” mobilizes our most powerful cognitive faculties, even when we know that no designer exists.

Consider the biologist confronting a puzzling anatomical structure. Asking “what is this organ for?” is not a commitment to divine design or Lamarckian teleology; it is a research strategy that has proven extraordinarily fruitful. Darwin himself reasoned teleologically in this methodological sense: the question “what adaptive problem does this trait solve?” guided his investigations even as his theory eliminated teleology from the ontology of biology.

The Principle of Optimal Coherence licenses and systematizes this methodological teleology. When we encounter an anomalous element in a coherent system and ask “what coherence does this ensure?” we are asking, in effect, “if I were designing a system subject to these constraints, why would I include this element?” The “designer” here is a fiction—a cognitive scaffold—but the reasoning it enables is genuine and productive.

This approach is safe precisely because it makes no ontological claims. We do not assert that the universe has purposes; we use purposive reasoning as an instrument of discovery. The teleological question “what is it for?” is reinterpreted as the constraint-based question “what coherence condition does it satisfy?” The former is a heuristic that activates human intuition; the latter is the scientifically respectable translation. By moving fluidly between these formulations, the investigator can exploit the power of teleological cognition while remaining within the bounds of legitimate scientific methodology.

In this sense, the rehabilitation of teleology proposed here is strictly limited: teleology as ontology remains inadmissible, but teleology as epistemology—as a tool for generating hypotheses and guiding inquiry—is not only admissible but indispensable. The Principle of Optimal Coherence provides the framework within which this methodological teleology can be safely and productively deployed.

10 Historical Note

The idea underlying the principle has a long history. Gottfried Wilhelm Leibniz, in his *Theodicy* (1710), formulated the thesis that our world is the best of all possible worlds. Notably, while composing the text in French, Leibniz used the Latin word *optimum* rather than the French *meilleur*. *Optimum* (from *ops*—strength, capability) means not "most pleasant" or "morally best" but "maximally realizable," "most achievable." This choice was most likely deliberate: as the *Monadology* makes clear, Leibniz was first and foremost a logician and mathematician, not a theologian. His "God" functions more as a logical principle of selection than as a personal deity. Leibniz almost certainly did not intend the moral-evaluative sense that Voltaire would later attack in *Candide*. The structural interpretation of *optimum*—as maximal realizability rather than moral goodness—is more consistent with the rigor of his philosophical system.

Leibniz also developed the concept of compossibility: not all possible things can exist together, just as an unstoppable force and an immovable object, each conceivable in isolation, cannot coexist in one system. This is close to our notion of constraints ensuring coherence. More significantly, Leibniz formulated a theory of "striving possibles" in which each essence tends toward existence in proportion to its "degree of perfection" or "quantity of essence." As Terekhovich (2018) has shown, this Leibnizian framework finds a striking echo in the principle of least action: the actual path is that which possesses the highest "degree of essence," measured physically by minimal action. The "competition" among possible paths for actualization is not a metaphor but a structural feature of how possibility relates to actuality. This connection between early modern metaphysics and contemporary physics suggests that the principle of optimal coherence is not merely a new heuristic but a recovery and clarification of insights present in the Western philosophical tradition since Leibniz.

Nevertheless, Leibniz presented this insight within the framework of theodicy—the justification of God in the face of evil—and invoked "God's choice" among possible worlds to preserve free will and to refute Spinoza's determinism. This theological packaging obscured the structural core of his thesis. Voltaire's *Candide* (1759) attacked the moral reading of "best possible world"—a reading that was likely never Leibniz's primary intention. Tellingly, while Voltaire used the word *Optimisme* in the subtitle of *Candide*, in the text itself he consistently speaks of *le meilleur des mondes possibles*. This substitution—*optimum* in the title, *meilleur* in the argument—reveals that Voltaire was attacking a moral interpretation that he himself had attributed to Leibniz, not the structural meaning embedded in the original term. Moreover, Leibniz died in 1716, forty-three years before *Candide* appeared. He had no opportunity to defend his position or to clarify what he had meant by *optimum*. Voltaire was attacking not a living interlocutor but a simplified, moralized caricature of Leibnizian philosophy that had become a salon commonplace.

There is a certain irony in this. Voltaire was a popularizer of Newtonian physics in France; his *Éléments de la philosophie de Newton* (1738) introduced the French public to the new science. He was well acquainted with Maupertuis, who formulated the principle of least action in 1744, and knew that in physics nature "chooses" optimal paths. Yet he did not see—or did not wish to see—the connection between *optimum* in Leibniz's metaphysics and *optimum* in variational physics. The satirical target was too tempting; the philosophical nuance, inconvenient. Serious analysis of the underlying structural insight became largely neglected for centuries.

Spinoza, for his part, asserted the necessity of the existent: everything that can exist does exist, and nothing could be otherwise. This is closer to our principle, but without the concepts of coherence and constraints, it remains pure determinism.

We maintain that there is no contradiction between the positions of Leibniz and Spinoza once the concept of a coherent system is introduced. There exist conditions of coherence. Configurations violating these conditions do not form coherent systems—they either do not arise or fall apart (decoherence). Thus, from the very definition of a coherent system, it follows that it exists in a state optimal for its coherence. No "choice" is required; the "multitude of alternatives" is a logical fiction.

11 Conclusion

The principle of optimal coherence is not a discovery about the nature of reality but a methodological tool. It directs the investigator's attention: when encountering something strange in a system, seek the constraint that this "strangeness" ensures. It prevents an error: declaring a load-bearing column a defect before verifying what it supports. It increases the efficiency of inquiry: the hypothesis of structural necessity is more productive than the hypothesis of randomness as a starting point.

The principle is not deductively provable and does not claim universal truth. Its value lies in application.

A Practical Workflow for Applying the Principle

When an investigator encounters strange, anomalous, or apparently suboptimal data within a system, the following workflow operationalizes the Principle of Optimal Coherence:

Step 1: Verify the data. Check for measurement error, instrumentation artifacts, or data corruption. If the anomaly disappears upon re-measurement or recalibration, it was noise. Proceed only if the anomaly persists.

Step 2: Rule out external interference. Determine whether the anomaly results from factors outside the system under investigation—environmental contamination, uncontrolled variables, or interaction with adjacent systems. If the anomaly can be attributed to external causes, address those causes. Proceed only if the anomaly is intrinsic to the system.

Step 3: Test for vestigiality. Consider whether the anomalous element is a genuine relic—a feature that once served a function but no longer does due to changed conditions. Historical analysis or comparative study with related systems may clarify this. If the element is demonstrably vestigial, it may be treated as contingent. Proceed only if vestigiality cannot be established.

Step 4: Apply the Principle. Once noise, external interference, and vestigiality have been eliminated, treat the anomaly as an integral part of the system. Assume it is load-bearing. Ask: What would fail, collapse, or become incoherent if this element were absent? What constraint does it satisfy? What other elements of the system depend on it?

Step 5: Systematically enumerate possible roles. Construct a comprehensive list of all possible roles the anomalous element might play in the system, then investigate and rule them out one by one. Consider at minimum:

(a) **Structural role**—does the element provide physical, logical, or organizational support to other components?

(b) **Functional role**—does it perform a specific operation, transformation, or process?

(c) **Regulatory role**—does it modulate, constrain, or control other elements?

(d) **Protective role**—does it buffer, shield, or stabilize the system against perturbations?

(e) **Informational role**—does it carry, store, or transmit information necessary for system operation?

(f) **Relational role**—does it mediate interactions between other components?

(g) **Boundary role**—does it define or maintain the system's limits or identity?

Each candidate role should be tested against available evidence until either a coherence-ensuring function is identified or all plausible roles have been eliminated.

Step 6: Seek the pivotal role. Investigate how the anomalous element might be not merely necessary but pivotal—a keystone that holds together multiple aspects of the system's coherence. The most "strange" features often turn out to be the most fundamental, precisely because they resist assimilation into familiar categories.

A note on teleological reasoning. Throughout this process, it is productive to adopt a teleological perspective—to ask "what is this for?" as if the element had been designed—even though the system may have no designer and no purpose. This is not a metaphysical commitment but a heuristic stance. Optimal elements in coherent systems typically exhibit a "fit" that resembles design: they appear precisely suited to their role, as if crafted for it. This apparent purposiveness is a signature of constraint-satisfaction. By reasoning as if the anomaly were designed, the investigator is more likely to discover the structural necessity it fulfills. The teleological question "what is it for?" is thus reinterpreted as "what coherence does it ensure?"

A note on "cheat" functions. Pay special attention to elements that appear to circumvent apparently insurmountable barriers—what might be called "cheat" functions. Coherent systems often exploit subtle physical or logical loopholes to achieve configurations that seem impossible under naive analysis. A paradigmatic example is quantum tunneling in stellar thermonuclear fusion: classical physics suggests that protons at stellar core temperatures lack sufficient energy to overcome their mutual Coulomb repulsion, yet fusion occurs because quantum mechanics permits tunneling through the barrier. Without this "cheat," stars could not shine and the universe as we know it could not exist. When an anomalous element appears to violate a constraint, ask whether it might instead be exploiting a deeper feature of reality that permits the apparent violation. Such elements are often the most fundamental load-bearing structures precisely because they enable what would otherwise be impossible.

A note on multifunctionality. Do not assume that an element serves only one function. Nature characteristically achieves coherence through multifunctional elements—single structures that simultaneously satisfy multiple constraints. Water, for instance, serves as solvent, thermal buffer, transport medium, and structural component in biological systems. DNA encodes genetic information while also providing structural organization to chromosomes. In economics, money functions simultaneously as medium of exchange, unit of account, and store of value. When investigating an anomalous element, consider that its "strangeness" may arise from the superposition of multiple roles that are not immediately apparent when analyzed in isolation. An element that seems suboptimal for one function may be precisely optimal for the conjunction of several functions. The investigator should therefore ask not only "what is this for?" but "what else is this for?"—and seek the configuration that represents the best compromise among competing functional demands.

Step 7: Specify falsification conditions. To guard against confirmation bias, explicitly state what observations would lead you to abandon the hypothesis of structural necessity. If, after sustained and rigorous inquiry, no coherence-ensuring function can be identified, the element should be provisionally reclassified as contingent or genuinely accidental.

This workflow embodies the core insight of the Principle: the hypothesis of necessity is more productive than the hypothesis of randomness as a starting point—but it must remain a hypothesis, subject to empirical discipline and the possibility of refutation.

The practical payoff of this approach is substantial. The history of science is replete with cases where anomalous features were dismissed as noise, accidents, or evolutionary relics for decades—only to be later recognized as essential to system function. The discovery of such necessity has often been serendipitous, occurring only when an investigator happened to ask the right question or stumbled upon the right evidence. The Principle of Optimal Coherence, operationalized through this workflow, transforms what has historically been a matter of luck into a systematic research strategy. By directing the investigator to assume structural necessity from the outset, and to systematically enumerate and test possible roles, this approach front-loads the search for function. It eliminates decades of fruitless dismissal and accelerates the discovery of load-bearing structures. What was once an occasional, accidental insight becomes a methodological imperative.

References

Adlam, E. (2022). Laws of Nature as Constraints. *Foundations of Physics*, 52(1), 1–41.

Butterfield, J. (2004). Some Aspects of Modality in Analytical Mechanics. In *Formal Teleology and Causality in Physics*. Paderborn: Mentis.

Chen, E. K. (2024). *Laws of Physics*. Cambridge: Cambridge University Press.

Chen, E. K., & Goldstein, S. (2022). Governing Without a Fundamental Direction of Time: Minimal Primitivism about Laws of Nature. In Y. Ben-Menahem (Ed.), *Rethinking the Concept of Law of Nature* (pp. 21–64). Cham: Springer.

Gell-Mann, M. (1994). *The Quark and the Jaguar: Adventures in the Simple and the Complex*. New York: W. H. Freeman.

Gell-Mann, M., & Lloyd, S. (1996). Information Measures, Effective Complexity, and Total Information. *Complexity*, 2(1), 44–52.

Glick, D. (2023). The Principle of Least Action and Teleological Explanation in Physics. *Synthese*, 202(1), 1–15.

Kriger, B. (2024). *No Final Theory: Law of Scale-Specific Principles*. Amazon.

Lange, M. (2017). *Because Without Cause: Non-Causal Explanations in Science and Mathematics*. Oxford: Oxford University Press.

Lange, M. (2023). Explanations by Constraint: Not Just in Physics. *Ergo: An Open Access Journal of Philosophy*, 12(16).

Langton, C. G. (1990). Computation at the Edge of Chaos: Phase Transitions and Emergent Computation. *Physica D*, 42(1–3), 12–37.

Meacham, C. J. G. (2025). Primitive Global Constraint Accounts of Laws. *Philosophy Compass*, forthcoming.

Terekhovich, V. (2018). Metaphysics of the Principle of Least Action. *Studies in History and Philosophy of Science Part B*, 62, 189–201.