

From Beliefs to Truth: How the Architecture of the Web Builds Programs from Coherence as Truth

Abstract

How do beliefs become truth? This paper develops an account of truth as architectural achievement within hierarchically organized knowledge systems. Drawing on Quine’s web of belief, we explicate the mechanism of functional transformation: predicates migrate from tentative hypotheses to core infrastructure through sustained pragmatic validation, achieving truth not by corresponding to abstract facts but by occupying stable positions in viable knowledge architectures. The framework resolves traditional coherentism’s isolation objection by grounding coherence in demonstrated viability measured through systemic brittleness—accumulated costs signaling misalignment with reality’s constraint structure.

The paper’s central innovation is showing that even logic itself—paradigm of necessary, *a priori* truth—achieved its foundational status through this mechanism. Logic emerged from proto-logical patterns in organisms selected for billions of years, was explicitly codified by ancient philosophers, underwent sustained pragmatic validation across all domains, and achieved core status through accumulated dependencies making revision functionally impossible for bounded agents. Logic’s apparent necessity reflects its earned architectural position after maximal validation, not metaphysical privilege.

We develop the five-stage progression of functional transformation (initial hypothesis, local validation, Standing Predicate formation, convergent core entry, hard core status) and show how it operates uniformly from domain-specific scientific predicates to foundational logical principles. The framework introduces three levels of truth (contextual coherence, justified truth, objective truth) corresponding to different degrees of validation, explains differential activation patterns in response to recalcitrant experience, and demonstrates how coherence builds computational closure through Markov blanket formation.

The germ theory case study illustrates the framework in action: miasma theory accumulated brittleness through mounting anomalies, germ theory entered as a competing hypothesis, pragmatic validation drove functional transformation, and new activation patterns stabilized with logic remaining constantly operative as the inferential machinery for theory evaluation. The framework dissolves traditional epistemological dichotomies (*a priori/a posteriori*, analytic/synthetic), naturalizes epistemic norms without relativism, and generates testable predictions for cognitive science and evolutionary epistemology. Truth emerges as thermodynamically stable, pragmatically validated, computationally closed architectural achievement.

1. Introduction

How do beliefs become truth? The traditional answer invokes correspondence: a belief is true when it matches an independent reality. But this answer raises more questions than it resolves. What is this “matching” relation? How do we access reality independently of our beliefs to check the correspondence? And how do we explain why some beliefs that once seemed perfectly matched to reality (the geocentric cosmos, phlogiston, miasma theory) were later revealed as systematically false?

This paper develops a radically different answer. Beliefs become truth not by corresponding to a Platonic realm but through a functional transformation within the architecture of knowledge systems. Truth is an achievement, not a discovery—a status earned through pragmatic validation rather than a relation to abstract facts. More specifically, truth emerges when beliefs undergo a progression from tentative hypotheses to validated tools, eventually becoming core programs that structure inquiry itself.

The radical implication: even logic itself—the paradigm of necessary, *a priori* truth—achieved its foundational status through this same mechanism, not through metaphysical privilege. This claim may seem counterintuitive, perhaps even absurd. But we will show that logic’s apparent necessity reflects extreme pragmatic entrenchment earned through maximal validation across the longest timescale and widest scope. Understanding this mechanism illuminates both how truth emerges architecturally and why logic occupies its special position within viable knowledge systems.

The central claim is architectural: the Quinean “web of belief” is not merely a metaphor for how knowledge is organized but the essential mechanism through which truth emerges from coherence. The web’s layered, hierarchical structure enables differential activation of predicates in response to experience, with some beliefs (like logic itself) constantly active at the core while others activate only for specific anomalies at the periphery. This architecture transforms coherence from a static property into a dynamic process: beliefs that maintain coherence under sustained pragmatic pressure migrate toward the network’s core, achieving functional unrevisability and, ultimately, truth.

How did logic achieve this status? Not through *a priori* necessity but through maximal pragmatic success. Logic is not a foundation that grounds inquiry from outside but a Standing Predicate that has proven maximally successful across the longest timescale and widest application range. Any learning system must implement logical structure to succeed, not because logic enjoys metaphysical privilege but because systems lacking logical inference fail in practice. Logic wasn’t “tested by logic” (which would be circular) but tested by reality through billions of years of selection pressure on organisms and knowledge systems. Systems with modus ponens outperformed those without; contradictory belief systems collapsed under their own incoherence; logical structure proved thermodynamically efficient at carving reality.

This emergence narrative dissolves the traditional distinction between *a priori* and *a posteriori* truth. All knowledge sits on the same continuum, distinguished only by degree of entrenchment and scope of successful application. Logic occupies the extreme end—maximally entrenched, maximally validated—but it achieved that position through the same pragmatic filtering that elevated germ theory from hypothesis to medical cornerstone. The difference is one of timescale and dependency relations, not fundamental kind.

1.1 The Puzzle of Logical Necessity

The orthodox view treats logic as categorically different from empirical beliefs. Mathematical and logical truths are necessary, known *a priori*, immune to empirical revision. Scientific beliefs are contingent, known *a posteriori*, perpetually subject to empirical falsification. This metaphysical divide has structured epistemology since Kant.

But this division faces persistent difficulties. Quine argued that no belief is immune to revision in principle, including logic. The development of non-Euclidean geometries showed that mathematical “necessities” can be revised when empirical pressure accumulates. Quantum mechanics has inspired paraconsistent and non-distributive logics. Even the law of excluded middle has been questioned in intuitionistic mathematics. If logic is genuinely *a priori* and necessary, how can we make sense of these developments?

The standard response distinguishes revision of logical systems from revision of logic itself: we can develop alternative formal systems while still using classical logic as the metalanguage for reasoning about them. But this response merely relocates the puzzle. Why is classical logic the default metalanguage? What grounds its privileged status?

Some philosophers appeal to reflective equilibrium: logic is justified by its coherence with our rational intuitions. But coherentist justifications face the isolation objection—couldn’t a system be perfectly coherent yet detached from reality? Others appeal to self-evidence: logical truths are justified by being immediately obvious. But obviousness is an unreliable guide, as the history of mathematics demonstrates (many once-obvious principles have been revised).

We propose a different resolution. Logic’s apparent necessity and immunity to revision are not metaphysical features but pragmatic consequences of its functional role within knowledge systems. Logic has achieved maximal entrenchment because it has proven maximally successful. The “necessity” we attribute to logic is really extreme functional indispensability combined with prohibitive revision costs. Logic is constantly active in all inquiry because questioning it requires using it—a pragmatic circularity that locks it in place, not a metaphysical guarantee of its truth.

1.2 Confronting the Circularity Objection

A natural objection arises immediately: Isn’t this account circular? To claim that organisms with modus ponens outperformed those without already employs logical inference. We cannot evaluate logic’s pragmatic success without using logic to draw that conclusion. How can we explain logic’s emergence through selection when the very concept of selection presupposes cause-effect reasoning that itself depends on logic?

We accept this. There is no logic-free vantage point from which to evaluate logic. Any account we give, any argument we construct, any explanation we offer will necessarily employ the logical principles we’re trying to explain. This circularity is inescapable.

But this is not vicious circularity. The story we tell is not a *justification* of logic from some external, logic-independent foundation—which would indeed be impossible. Rather, it is an *explanation* of how logic became entrenched to the point of functional unrevisability within the systems that employ it. We are not trying to prove logic is reliable without using logic (which would be circular

reasoning). We are explaining why the circle exists and why we cannot step outside it.

The circularity itself reveals logic's functional indispensability. The impossibility of logic-free evaluation is not a flaw in our account—it is a datum our account explains. Logic achieved such deep entrenchment through accumulated pragmatic success that questioning it now requires using it. This pragmatic lock-in, not metaphysical necessity, explains why logic feels unrevisable from within any system that employs it.

Consider an analogy: we cannot evaluate whether color vision accurately represents wavelengths without using color vision (or instruments calibrated to our color experience). This doesn't mean color vision is unjustified or that claims about color are circular. It means the justificatory question is ill-formed at that level of perceptual architecture. Similarly, logic operates at a level of cognitive architecture where external justification is not merely difficult but conceptually confused. Logic provides the operating system for justification itself.

This connects to a broader pattern throughout the framework: Standing Predicates at each architectural level achieve computational closure, making reasoning possible at that level without constant reference to lower-level implementation details. At the deepest level, logic provides closure for inference itself. All reasoning employs logical structure; there is no meta-level reasoning that doesn't presuppose logic. The circularity indicates that logic occupies the operating-system layer, not that the account fails. Our framework explains this closure as the result of maximal pragmatic validation creating functional indispensability.

1.3 The Architectural Solution

This paper explicates the mechanism through which beliefs achieve truth-status by examining the architecture that enables this transformation. The Quinean web of belief provides more than a useful metaphor; it supplies the structural conditions that make functional transformation possible.

Three architectural features prove essential. First, holistic interconnection: knowledge forms networks where beliefs mutually support or inhibit each other, and revisions ripple through the entire system. Second, layered organization: beliefs organize hierarchically from observational periphery to abstract core, with systematic dependency relations between layers. Third, differential activation: different beliefs activate in response to different experiences, with core beliefs remaining constantly active while peripheral beliefs activate episodically.

These features enable a distinctive kind of coherence that avoids the isolation objection. Traditional coherentism requires only internal consistency within a belief system, which fictional or delusional systems can easily satisfy. But architectural coherence demands that beliefs maintain mutual support under sustained pragmatic pressure from reality. When observations conflict with predictions, when interventions fail, when anomalies accumulate—these pragmatic challenges force revisions that ripple through the network. Systems that maintain coherence despite this pressure demonstrate genuine viability, not mere internal consistency.

Crucially, the architecture enables functional transformation of successful beliefs. When a predicate (the reusable component of a proposition, like "...is an infectious disease") repeatedly succeeds across diverse applications, it undergoes a

status change: from tested-data to tool-that-tests. Initially, “this illness is infectious” is a hypothesis evaluated against alternatives. After extensive validation, “...is an infectious disease” becomes a diagnostic category that structures medical inquiry itself. It’s no longer tested but used to test other claims.

This transformation has thermodynamic significance. Standing Predicates (as we call these promoted tools) achieve computational closure: they allow reasoning about coarse-grained variables without tracking underlying micro-details. A physician diagnosing infectious disease need not calculate viral protein configurations or immune cell dynamics; the predicate compresses that complexity into tractable categories. This compression minimizes cognitive costs, enabling efficient prediction and intervention.

The web architecture makes this compression possible through layered organization. Standing Predicates at one level provide the tools for inquiry at the next level. “...is an infectious disease” presupposes biological categories, which presuppose material ontology, which presupposes logical principles. Each layer achieves computational closure by drawing boundaries (Markov blankets, in information-theoretic terms) that shield internal reasoning from lower-level complexity.

Logic occupies the deepest layer because it provides the closure conditions for inquiry itself. One cannot investigate whether modus ponens is reliable without already employing modus ponens to structure the investigation. This is not vicious circularity but pragmatic lock-in: the functional role logic plays makes it simultaneously indispensable and untestable within the system. Yet this status was earned, not given. Proto-logical inference patterns in early organisms proved successful; explicit logical rules codified by ancient philosophers proved successful; attempts to develop coherent systems violating logic proved unsuccessful. Logic achieved its core position through the same pragmatic filtering that operates throughout the network, just on the longest timescale.

1.4 Coherence as Truth

The framework offers a deflationary account of truth combined with a substantive theory of how truth is achieved. Deflationarily, “is true” doesn’t denote a substantive property like correspondence to abstract facts. Instead, it tracks functional role within viable knowledge systems. To say “germ theory is true” is to say it occupies a certain position in low-brittleness medical networks, has survived extensive pragmatic testing, and enables successful prediction and intervention.

But this is not mere relativism. Knowledge systems face external constraints from reality. When systems misalign with these constraints, they accumulate what we call systemic brittleness: mounting costs from failed predictions, ineffective interventions, accumulating anomalies, and ad hoc modifications. A perfectly coherent flat-earth cosmology would generate catastrophic navigational costs. A coherent phlogiston chemistry would require endless patches to accommodate combustion phenomena. These systems aren’t just false; they’re structurally unstable, generating escalating costs that force revision or collapse.

Coherence builds truth through a multi-stage process. Initially, beliefs are merely contextually coherent (Level 3 truth): they fit consistently within some knowledge system, but this proves nothing about viability. Fictional systems like Sherlock Holmes stories achieve contextual coherence without aiming at truth. Next,

beliefs that maintain coherence under pragmatic testing earn the status of justified truth (Level 2): they're certified by low-brittleness networks demonstrating real-world viability. Finally, beliefs that multiple independent inquiry paths converge upon despite different starting points and methods achieve objective truth (Level 1): they align with the constraint-determined structure of optimal solutions.

Logic exemplifies this progression. Proto-logical inference patterns were initially just contextually coherent behavioral regularities in organisms. As these patterns were explicitly formulated and systematically tested across diverse domains, they earned justified truth status—demonstrating their reliability in supporting successful reasoning. Finally, as completely independent inquiry traditions (Western philosophy, Indian logic, Chinese philosophy, modern formal systems, artificial intelligence) all converged on implementing essentially similar logical principles, logic achieved objective truth status. Not because it corresponds to abstract logical facts but because it represents the convergent solution to the problem of viable inference.

This convergent discovery provides evidence for objectivity, but we should be precise about what kind of objectivity. One interpretation: the convergence might be species-universal—all human traditions converge because we share cognitive architecture shaped by similar evolutionary pressures. On this view, logic is objective for humans but might differ for minds with different evolutionary histories. A stronger interpretation: the convergence is mind-independent—any possible learning system facing pragmatic constraints would converge on these logical structures.

We defend the stronger thesis. The constraints driving convergence toward logical structure are not species-specific but follow from the general requirements of any system that must (a) act based on limited information, (b) maintain internal models of its environment, and (c) face costs for prediction failures. Non-contradiction is favored because contradictory models generate incoherent action, as we showed in the evolutionary account. Valid inference is favored because it preserves truth across reasoning chains, enabling knowledge to guide behavior reliably. These pressures are domain-general, not human-specific.

Crucially, artificial systems provide independent evidence: machine learning systems develop modus-ponens-like inference patterns without being explicitly programmed for them, because such patterns reduce prediction error. This human-AI convergence cannot be explained by shared biological heritage—the systems have radically different implementations. The best explanation is constraint-determined structure: logical principles reflect the solution to general problems any predictive system faces. This doesn't prove mind-independence conclusively, but it shifts the burden of proof. If logic were merely species-universal, we would need to explain why artificial systems with different implementations converge on similar structures.

This explains why logic feels necessary while remaining naturally explicable. Necessity is pragmatic indispensability, not metaphysical privilege. Logic has proven so successful across such a wide range that no viable alternative has emerged, and the cost of attempting revision would be astronomical (requiring re-derivation of all dependent structures). For bounded agents, this makes logic functionally unrevisable even though it's not metaphysically necessary.

1.5 Structure and Genesis

This paper develops two complementary perspectives on how web architecture enables truth. The synchronic perspective examines the layered structure of knowledge systems at a moment in time: which predicates occupy which layers, what dependency relations hold between them, which beliefs activate in response to which experiences. This explains the present organization of knowledge and the functional roles different beliefs play.

The diachronic perspective traces how this structure emerged over time: how proto-logical patterns evolved into explicit logical systems, how tentative hypotheses migrate toward the core through successful application, how Standing Predicates emerge from repeated pragmatic validation. This explains why particular beliefs occupy particular positions and why some transformations succeed while others fail.

Both perspectives are essential. The synchronic view shows how the architecture functions: why logic remains constantly active, why domain-specific predicates activate contextually, how computational closure emerges at different levels. The diachronic view shows how this architecture came to exist: through Lamarckian-style directed adaptation, with successful practices cached into programs and unsuccessful ones relegated to a “Negative Canon” of abandoned approaches.

Throughout the paper, these perspectives interweave. When examining activation patterns (synchronic), we explain why certain beliefs earned constant activation status (diachronic). When examining functional transformation (diachronic), we explain what roles the transformed predicates play in current inquiry (synchronic). The architecture emerges through functional transformation, and functional transformation operates within the architecture.

1.6 Scope and Roadmap

This paper develops a standalone account of how web architecture enables truth to emerge from coherence through differential predicate activation and functional transformation. While it draws on and complements the broader framework of Emergent Pragmatic Coherentism (EPC), it can be read independently. Readers need not be familiar with EPC’s full apparatus—systemic brittleness metrics, constraint network models, evolutionary dynamics—to follow the present argument. We focus specifically on the mechanism by which beliefs become truth through architectural position.

Section 2 establishes foundations by distinguishing beliefs, propositions, and predicates, explaining how Standing Predicates emerge, and introducing deflationary truth. Section 3 explicates the layered architecture of knowledge networks, showing how predicates organize hierarchically and achieve computational closure at different levels. Section 4 examines activation dynamics: which predicates activate in response to which experiences, and why core predicates like logic remain constantly active. Section 5 details functional transformation: the five-stage progression through which predicates migrate from hypothesis to core infrastructure, with extended treatment of logic’s path through these stages. Section 6 explains how coherence becomes truth through this architectural process, contrasting our view with traditional coherentism. Section 7 provides a worked example using germ theory’s displacement of miasma theory, showing how medical predicates underwent functional transformation. Section 8 addresses objections regarding relativism, logical revisability, and the status of mathematics. Section 9 explores implications for philosophy of science,

epistemology, logic, cognitive science, and evolutionary epistemology. Section 10 concludes by synthesizing the emergence narrative.

The central claim bears repeating: truth is architectural achievement. Beliefs become true by achieving certain functional positions within viable knowledge systems organized as holistic, hierarchical webs. Even logic itself—the paradigm of necessary truth—earned its foundational status through pragmatic success, not metaphysical fiat. Understanding how web architecture enables this transformation illuminates both the structure of knowledge and the naturalistic basis of truth.

1.7 Relation to Quine's Framework

This paper builds fundamentally on Quine's naturalistic epistemology, but extends his framework in specific ways that warrant explicit clarification. We take the web metaphor seriously—perhaps more literally than Quine intended—by making its structure and dynamics mechanistically precise. This section distinguishes what we draw directly from Quine from our systematic elaborations, explaining why these additions serve rather than betray his philosophical project.

What We Take from Quine

Our framework inherits several core Quinean commitments. First, thoroughgoing naturalism: beliefs are dispositions to assent (Quine 1960, Word and Object), grounded in observable behavior rather than unobservable mental states or abstract propositions. Second, holism: beliefs form interconnected webs where no proposition is tested in isolation; empirical challenges engage entire belief clusters (Quine 1951, “Two Dogmas of Empiricism”). Third, the center-periphery structure: beliefs organize along a gradient from observational periphery to abstract core, with logic occupying the center (Quine and Ullian 1978, The Web of Belief). Fourth, pragmatic revision: when experience conflicts with theory, adjustments can occur anywhere in the web, guided by considerations of minimal disruption and maximum simplicity. Fifth, revisability in principle: no belief enjoys absolute immunity from revision, including logic and mathematics—though pragmatic costs make some revisions effectively prohibitive. Sixth, recalcitrant experience as driver of change: observations that resist accommodation force network restructuring (Quine 1960).

These commitments structure our entire approach. We are thoroughly Quinean in rejecting analytic/synthetic distinctions, embracing epistemological naturalism, and treating even logic as fallible in principle while practically entrenched.

What We Add Beyond Quine

Our extensions make Quine's metaphor mechanistically explicit while preserving his philosophical insights. First, we propose an explicit five-tier architecture (Sections 3.2-3.3) distinguishing logic (Tier 1), mathematics (Tier 2), domain-general predicates (Tier 3), domain-specific predicates (Tier 4), and observational reports (periphery). Quine described a center-periphery gradient but deliberately avoided sharp boundaries to preserve holism. We acknowledge this tension: our tiers are analytical tools with porous boundaries, not ontological categories. The systematization enables empirical predictions about revision patterns while risking over-rigidification of Quine's flexible framework.

Second, we introduce Standing Predicates (Section 2.4)—our terminology for what Quine might have called “well-entrenched beliefs.” The term emphasizes their functional role as reusable programs that structure inquiry rather than

merely their degree of entrenchment. This highlights the status change from tested-data to tool-that-tests, which Quine noted but didn't systematically develop.

Third, we articulate a five-stage functional transformation mechanism (Section 5.1) explicating how predicates migrate from hypothesis to core infrastructure. While Quine recognized that beliefs can become entrenched through use, he didn't provide a stage-by-stage account of this process. Our mechanism makes his insights testable by specifying criteria for each stage.

Fourth, we distinguish three levels of truth (Section 5.3): contextual coherence, justified truth, and objective truth. Quine's deflationary approach to truth emphasized that "is true" serves primarily logical functions rather than denoting a substantive property. We preserve this deflation while adding structure to track different degrees of pragmatic validation—from mere internal consistency to convergent discovery across independent inquiry traditions.

Fifth, we develop differential activation dynamics (Section 4) showing which predicates activate in response to which experiences. While Quine noted that core beliefs are harder to revise than peripheral ones, we make this explicit through activation patterns: logic remains constantly active (operating system), domain predicates activate contextually, observational predicates activate episodically. This extends Quine's cost-benefit analysis of revision into a dynamic framework.

Sixth, we employ information-theoretic concepts unavailable to Quine: computational closure via Markov blankets (Section 3.4-3.5), drawing on Pearl (1988) and Friston (2010). These formalize Quine's intuition that successful predicates enable efficient reasoning by shielding us from lower-level complexity. The formalism is modern, but the insight is Quinean.

Why These Additions

These extensions serve three purposes compatible with Quine's naturalistic project. First, they make the web metaphor empirically testable by generating specific predictions: brain damage should selectively affect predicates by tier; scientific revisions should typically preserve deeper layers; AI systems should independently discover logical structure. Second, they resolve problems Quine acknowledged but left open—particularly coherentism's isolation objection. By grounding coherence in demonstrated viability measured through brittleness accumulation, we provide the external constraint coherentism needs without reintroducing foundationalism. Third, they systematize Quine's scattered insights about entrenchment, revision costs, and pragmatic filtering into a unified account of how beliefs become truth.

One Tension: System vs. Holism

Our five-tier structure might seem to violate Quine's resistance to sharp boundaries. Quine deliberately kept the web flexible precisely to avoid the kind of systematization we propose. We acknowledge this tension but defend our approach as analytical rather than ontological. The tiers are not discrete categories but regions along continua of scope, dependencies, entrenchment, and revision cost. Boundaries are porous—predicates occupy positions on gradients rather than belonging exclusively to one tier. We view this as making Quine's gradient explicit for analytical purposes rather than replacing his holism with rigid categories.

The systematization enables questions Quine's framework left vague: exactly how entrenched is mathematics compared to logic? What makes revision costs

“prohibitive” for some beliefs but manageable for others? When does a belief migrate from periphery toward core? Our framework provides answers while preserving Quine’s core insight that these are pragmatic matters of degree, not metaphysical facts about belief categories.

Continuity with Quine’s Project

Despite these extensions, we remain faithful to Quine’s naturalistic vision. We reject correspondence theories of truth, embrace thoroughgoing fallibilism, ground epistemology in empirical practice, and explain even logic’s centrality through pragmatic success rather than metaphysical necessity. Where Quine provided the metaphor and philosophical foundations, we supply mechanical details. Where he emphasized flexibility, we add structure for empirical testing. Where he noted patterns qualitatively, we measure them quantitatively. But the philosophical project—naturalizing epistemology while avoiding relativism—remains Quinean throughout.

2. Foundations: Beliefs, Propositions, Predicates

This section establishes the conceptual foundations for understanding how beliefs become truth through architectural transformation. We begin with the naturalistic basis of belief in dispositions, move to the functional role of predicates as reusable components, introduce a deflationary account of truth, and conclude by explicating the general mechanism through which predicates achieve Standing status.

2.1 From Dispositions to Articulation

Following Quine (1960), we ground belief in observable behavior rather than in unobservable mental states. A belief is fundamentally a disposition to assent—a stable pattern of behavior that manifests publicly. To believe “it is raining” is to be disposed to say “yes” when asked about rain, to reach for an umbrella, to plan indoor activities, and so forth. This dispositional foundation provides thoroughgoing naturalism: beliefs are patterns in an organism’s behavioral repertoire, not abstract propositions grasped by immaterial minds.

But organisms possess varying degrees of awareness of their own dispositions. Humans exhibit a distinctive capacity for what we might call dispositional self-monitoring—the ability to recognize and report on their own behavioral patterns. This monitoring capacity is itself constituted by higher-order dispositions: dispositions about dispositions, implemented in neural architecture through recursive feedback loops. When I report “I believe it is raining,” I’m articulating a higher-order disposition to assent about my first-order disposition to assent to the sentence “It is raining.”

This move acknowledges the functional importance of self-monitoring while remaining fully naturalistic. Consciousness and self-awareness are not non-physical additions to dispositional patterns but emergent properties of sufficiently complex, recursive dispositional structures. The subjective feeling of belief arises from these nested patterns, much as the subjective feeling of bodily position arises from proprioceptive feedback loops.

Beneath explicit beliefs lie what we term notions: pre-verbal dispositions that operate below conscious awareness. Notions are compressed patterns from accumulated experience that create directional tendencies—a “gravitational pull” toward certain conclusions without explicit formulation. An experienced physician might have a notion that a particular patient presentation is concerning without yet being able to articulate why. This notion represents a compressed pattern extracted from thousands of prior cases, operating as a prediction engine that signals potential danger.

The progression from notion to belief involves crystallization: the transformation of implicit dispositional patterns into explicit, linguistically articulable form. This crystallization typically occurs when action requires explicit justification, when social communication demands articulation, or when the disposition becomes strong enough to spontaneously enter awareness. Once crystallized, the belief becomes available for conscious evaluation and deliberate revision—it enters the space of reasons.

When articulated linguistically, a belief becomes a functional proposition: a public, testable claim that can be subjected to collective assessment. We adopt a deliberately deflationary approach here. A functional proposition is not an abstract, language-independent meaning but a concrete linguistic object—a sentence that multiple agents can evaluate. “Water boils at 100°C at sea level” is not a Platonic truth but a sentence that has proven remarkably useful for coordinating behavior and enabling successful prediction across diverse contexts.

This naturalistic foundation explains how private psychological states become public knowledge. Dispositions are behavioral patterns in individuals; when similar dispositions emerge across multiple agents facing shared constraints, the sentences they’re disposed to assent to converge. This convergence doesn’t require deliberate coordination—it emerges from parallel discovery as independent agents learn from the same constraint landscape.

2.2 Predicates as Reusable Components

Propositions have internal structure. The sentence “Cholera is an infectious disease” attributes a property (being an infectious disease) to a subject (cholera). The attributive component—“...is an infectious disease”—is the predicate.

Predicates are functionally crucial because they’re reusable: the same predicate can apply to multiple subjects. Once we’ve established that cholera is infectious, we can apply the same predicate to tuberculosis, influenza, and novel diseases.

This reusability makes predicates the primary site of conceptual compression. Rather than storing independent facts about each disease, we compress regularities into predicates that can be extracted and generalized. The predicate “...is an infectious disease” compresses vast information: causal models (disease caused by pathogens), transmission mechanisms (person-to-person or environmental spread), intervention strategies (isolation, sanitation, sterilization), and diagnostic approaches (identify and culture the pathogen).

In information-theoretic terms, predicates function as Markov blankets—statistical boundaries that compress environmental complexity into stable variables enabling reasoning at coarse-grained levels (Pearl 1988; Friston 2013). When a physician applies “...is an infectious disease” to a novel illness, they draw a boundary that shields their reasoning from the infinite molecular complexity of viral proteins, immune responses, and cellular mechanisms. They can reason

productively using variables like “transmission vector,” “incubation period,” and “virulence” without tracking the underlying micro-dynamics.

This compression achieves what we call computational closure: the coarse-grained level forms a self-contained dynamical system where future states can be predicted from current states without reference to lower levels. You can predict disease spread using epidemiological models that track infection rates and transmission probabilities without modeling protein interactions. The predicate creates a new causal level through compression.

Predicates vary in their scope and reliability. Some predicates are tentative hypotheses still under evaluation: “...is caused by vitamin deficiency” might be proposed for a disease but not yet established. Other predicates have proven so consistently useful across so many contexts that they’ve earned a different functional status. We term these Standing Predicates.

2.3 Deflationary Truth + Functional Role

What does it mean to say a proposition is true? The correspondence theory answers: the proposition matches reality, there’s an isomorphism between linguistic structure and worldly facts. But correspondence faces well-known difficulties (Davidson 1986). How do we specify the matching relation without presupposing what we’re trying to explain? How do we access reality independently of our conceptual schemes to verify correspondence? And how do we explain the apparent truth of mathematical and logical propositions, which don’t seem to correspond to concrete facts?

We adopt a deflationary approach to truth combined with a substantive account of functional role. Deflationarily, “is true” doesn’t denote a deep metaphysical property. The truth predicate serves primarily logical and expressive functions—it enables us to generalize over propositions, to endorse claims without restating them, to reason about what others believe. Saying “Germ theory is true” doesn’t attribute a mysterious truth-making relation; it primarily serves to endorse germ theory.

But this deflationary move doesn’t make truth vacuous or subjective. While “is true” doesn’t denote correspondence to Platonic forms, it does track a substantive functional role: a proposition’s position within viable knowledge systems. To say a proposition is true is to say (roughly) that it’s certified by low-brittleness networks demonstrating real-world viability. Truth-attributions register pragmatic success, not metaphysical matching.

This generates multiple levels of truth-attribution corresponding to different degrees of validation. At Level 3 (contextual coherence), a proposition is “true” within some particular knowledge system—it coheres with other propositions in that system regardless of the system’s overall viability. Fictional systems like Sherlock Holmes stories achieve contextual coherence without aiming at truth in the correspondence sense. At Level 2 (justified truth), a proposition is certified by low-brittleness networks that have demonstrated viability through sustained pragmatic success. At Level 1 (objective truth), a proposition aligns with the constraint-determined structure that multiple independent inquiry paths converge upon—what we call the Apex Network.

This deflationary yet substantive account explains several puzzling features of truth. It explains why truth seems both normative (we ought to believe truths) and descriptive (truth tracks reality): the normativity emerges from pragmatic

consequences of misalignment with reality, while the descriptive dimension registers this pragmatic feedback. It explains why mathematical and logical truths seem necessary without requiring abstract objects: their “necessity” is really extreme entrenchment resulting from maximal pragmatic success across all domains. And it explains why truth seems both discoverable (we can be wrong about what’s true) and constraint-determined (there are objective facts): the constraints are real and mind-independent, but we access them through pragmatic filtering, not direct insight.

2.4 The General Mechanism of Standing Predicate Emergence

How do predicates achieve Standing status? This section explicates the general mechanism—a mechanism that operates uniformly from domain-specific scientific predicates all the way to logic itself. Understanding this mechanism is crucial for the emergence narrative developed throughout the paper.

Stage 1: Initial Proposal

A predicate begins as a tentative hypothesis within some knowledge system. Scientists propose “...is caused by infectious agents” as a candidate explanation for disease patterns. Mathematicians propose “...is a prime number” as a useful categorization of integers. Logicians propose “...follows by modus ponens” as a reliable inference rule. At this stage, the predicate is merely being-tested—it’s data under evaluation, not a tool for evaluating other claims.

Stage 2: Local Validation

Through repeated application across specific contexts, the predicate begins proving its utility. “...is caused by infectious agents” successfully explains cholera transmission, tuberculosis spread, and surgical infection rates. Each successful application reduces uncertainty (prediction error) and enables effective intervention. The predicate starts earning trust within its domain.

Crucially, this validation is pragmatic, not merely logical. The predicate doesn’t just cohere with other beliefs; it enables successful action in the world.

Treatments guided by germ theory work; interventions ignoring it fail. This pragmatic pushback from reality distinguishes viable predicates from merely coherent ones.

Stage 3: Functional Transformation

At some point, a qualitative shift occurs. The predicate transitions from tested-data to tool-that-tests—from being evaluated to doing the evaluating. When a physician encounters a novel illness, “...is an infectious disease” is not a hypothesis they consider alongside alternatives. It’s a diagnostic framework they immediately apply, using it to structure investigation: identify the pathogen, trace transmission, implement containment.

This transformation is functional, not merely psychological. The predicate’s role in reasoning changes. It becomes part of the background architecture that makes domain-specific inquiry possible. Questions shift from “Is this infectious?” to “What kind of infection is this? What’s the transmission route? What’s the appropriate treatment?” The predicate now unpacks a suite of proven methods rather than making a claim under evaluation.

Stage 4: Entrenchment

As the predicate continues proving successful, it becomes increasingly entrenched in the knowledge system. It gets codified in textbooks, institutionalized in medical protocols, embedded in regulatory frameworks, and taught as foundational knowledge. This entrenchment serves an efficiency function—it caches successful patterns to avoid re-deriving them from scratch each time.

The entrenchment has economic logic. Given bounded cognitive resources, it's thermodynamically expensive to constantly re-evaluate well-established principles. By caching proven predicates as background infrastructure, cognitive systems achieve computational efficiency. This is precisely analogous to how computers cache frequently-used calculations rather than recomputing them each time.

Stage 5: Migration to Core

For predicates with sufficiently broad scope and sustained success, a further transformation occurs: migration toward the network's core. The predicate becomes so widely presupposed by other inquiry that its removal would require re-deriving vast dependent structures. Its functional position shifts from domain-specific tool to general infrastructure.

Logic exemplifies this maximally. Logical predicates like "...follows by modus ponens" or "...is a contradiction" have proven useful across all domains of inquiry over the longest timescales. They've become so deeply embedded that questioning them requires using them—they provide the operating system for inquiry itself. This gives them functional unrevisability despite lacking metaphysical necessity.

The Mechanism's Generality

This five-stage progression operates uniformly across all predicates, from narrow scientific hypotheses to foundational logical principles. The difference is one of degree, not kind:

- **Scope:** Domain-specific predicates apply within particular contexts (medicine, chemistry); logic applies universally
- **Track record:** Recent predicates have decades of validation; logic has millennia
- **Dependencies:** Removing germ theory requires revising medicine; removing logic requires revising all inquiry
- **Timescale:** Scientific predicates migrate to Standing status across generations; logic achieved it over the entire history of thought

But the mechanism is identical: repeated pragmatic success → functional transformation → entrenchment → migration to core. Logic isn't categorically different from germ theory; it's the endpoint of the same process operating at maximum scope and timescale.

Why Some Predicates Achieve Standing Status

Not all predicates complete this progression. Many are proposed, tested, and abandoned. Miasma theory of disease, phlogiston theory of combustion, and luminiferous ether of light propagation all failed at Stage 2 or 3—they couldn't maintain pragmatic success under sustained testing.

What distinguishes successful predicates? Two factors prove crucial. First, thermodynamic efficiency: Standing Predicates achieve genuine computational closure, providing coarse-grained variables that enable prediction without tracking lower-level complexity. Failed predicates leak information—their boundaries don't align with reality's causal structure, requiring constant patches and adjustments (what we term high brittleness).

Second, convergent discovery: When multiple independent inquiry paths reach the same predicate despite different starting points and methods, this suggests the predicate is carving reality at genuine joints rather than imposing arbitrary structure. Germ theory was independently developed by multiple researchers across different contexts. Logic has been independently codified by completely separate intellectual traditions. This convergence indicates alignment with mind-independent constraint structure.

The mechanism of Standing Predicate emergence is therefore thoroughly naturalistic while avoiding relativism. Predicates don't achieve Standing status through social consensus or arbitrary convention. They earn it through demonstrated capacity to compress reality's structure efficiently, validated through pragmatic success and convergent discovery. The next section examines how these predicates organize architecturally into layered networks.

3. The Architecture: Layered Networks

Having established that Standing Predicates emerge through pragmatic validation, we now examine how these predicates organize into layered architectures. The Quinean web of belief is not a flat network but a hierarchically structured system with systematic patterns of dependency and activation. This section explicates the synchronic structure (how the architecture is currently organized) while integrating the diachronic story (how this organization emerged over time).

3.1 The Quinean Web Structure

Quine's metaphor of the “web of belief” captures three essential features of knowledge organization (Quine and Ullian 1978). First, holistic interconnection: beliefs don't stand in isolation but form mutually supporting or inhibiting networks. No belief is tested independently; empirical challenges always test entire belief clusters. Second, center-periphery gradient: beliefs organize spatially (metaphorically) from observational reports at the periphery to abstract principles at the core. Third, pragmatic revision: when experience conflicts with expectations, adjustments can occur anywhere in the web, with decisions guided by pragmatic considerations of minimal disruption.

These features are not arbitrary design choices but structural necessities for systems that learn from experience. Holism is required because reality presents phenomena, not isolated facts—understanding disease requires coordinating beliefs about biology, chemistry, causation, and observation. The center-periphery gradient emerges because some beliefs are presupposed by many others (logic, basic ontology) while others are relatively isolated (particular observations). Pragmatic revision is necessary because no belief is absolutely immune to reconsideration, yet some revisions are vastly more costly than others.

The web metaphor captures interconnection and flexibility but underspecifies structure. How many layers? What determines layer membership? What kinds of connections matter? We need to move from metaphor to mechanism.

The key insight is that beliefs organize hierarchically according to dependency relations and scope of application. Some predicates are rarely used and highly

specific (observational predicates like “...appears red to me now”). Others are constantly employed across all domains (logical predicates like “...is consistent with”). Between these extremes lie multiple intermediate layers of predicates with varying scope, entrenchment, and activation frequency.

This layered organization is not static. The web structure emerged gradually as inquiry progressed and predicates proved their utility. Early human knowledge systems were relatively flat—proto-logical patterns, basic causal reasoning, and observational generalizations existed without sharp differentiation. As inquiry advanced, successful predicates migrated toward the core through entrenchment, while new specialized predicates accumulated at the periphery. The architecture we observe today is the accumulated result of millennia of pragmatic filtering.

3.2 Hierarchical Layers of Predicates

The web organizes into at least five distinguishable layers, though boundaries between layers are somewhat porous. Each layer is characterized by scope of application, frequency of activation, number of dependent beliefs, and cost of revision.

Tier 1 Core: Logic and Fundamental Inference

At the deepest level lie logical predicates: “...is a contradiction,” “...follows by modus ponens,” “...is consistent with,” “...instantiates the law of non-contradiction.” These predicates are constantly active—they structure all inquiry regardless of domain. You cannot investigate chemistry without using modus ponens, cannot evaluate theories without checking consistency, cannot reason without employing logical inference rules.

Logic’s core position reflects maximal scope (applies everywhere), maximal dependencies (all inquiry presupposes it), and maximal entrenchment (proven over longest timescale). The cost of revising logic would be astronomical: every dependent structure would require re-derivation, effectively requiring rebuilding all knowledge from scratch. For bounded agents, this makes logic functionally unrevisable.

Crucially, this core status was earned, not given. Proto-logical inference patterns evolved in organisms because they enabled successful navigation of reality. Organisms that could infer “if predator-scent, then danger” and “predator-scent detected” therefore “danger” outperformed those that couldn’t. Explicit logical systems codified these successful patterns, and sustained pragmatic validation over millennia entrenched them at the core. Section 5 develops this emergence story in detail.

Tier 2: Mathematics and Universal Principles

The next layer contains mathematical predicates and universal physical principles: “...obeys conservation of energy,” “...satisfies the Pythagorean theorem,” “...follows from axioms of arithmetic.” These predicates activate across nearly all theoretical domains—physics, engineering, economics, biology all presuppose mathematics and thermodynamics.

Tier 2 predicates are less entrenched than logic (non-Euclidean geometry shows mathematical axioms can be revised; quantum mechanics questions energy conservation at microscopic scales) but still extraordinarily robust. They have enormous scope and deep dependencies—revising them requires re-deriving vast structures. The cost is prohibitive without compelling evidence.

Like logic, Tier 2 predicates achieved their position through pragmatic success. Early humans developed arithmetic through practical needs (counting, trading, construction). As these patterns proved reliable across expanding contexts, they became entrenched. Euclidean geometry dominated for two millennia because it worked perfectly at human scales. Only when inquiry reached cosmological and quantum scales did evidence accumulate for revising these principles—demonstrating that even Tier 2 predicates remain fallible despite their centrality.

Tier 3: Domain-General Standing Predicates

This layer contains predicates applicable across multiple but not all domains: “...is caused by,” “...is a disease,” “...is matter,” “...has spatial extension,” “...persists through time.” These predicates structure broad categories of inquiry but don’t activate universally.

Tier 3 predicates have moderate scope (apply in many contexts), substantial dependencies (specific theories build on them), and significant entrenchment (proven over centuries). Revising them is costly but manageable—when germ theory displaced miasma theory, the predicate “...is a disease” persisted while its analysis changed.

The emergence of Tier 3 predicates reflects accumulating theoretical sophistication. Early humans had cause-effect reasoning, disease concepts, and material ontology, but these remained implicit. As inquiry advanced, these patterns were explicitly formulated and systematically validated. Predicates that maintained utility across diverse contexts migrated toward this semi-core position, while those that failed remained peripheral or were abandoned.

Tier 4: Domain-Specific Standing Predicates

Domain-specific predicates apply within particular fields: “...is an infectious disease” (medicine), “...is an acid” (chemistry), “...is a mammal” (biology), “...is gravitationally bound” (astrophysics). These predicates structure inquiry within their domains but don’t activate outside them.

Tier 4 predicates have narrow scope (domain-specific), local dependencies (other domain beliefs build on them), and moderate entrenchment (proven over decades or centuries within the field). Revision costs are significant within the domain but limited outside it. When germ theory was established, medicine required substantial restructuring, but physics continued unchanged.

This layer exhibits the most dynamic activity in contemporary science. New predicates are constantly proposed, tested, and either migrated toward Standing status or abandoned. “...is a quark,” “...is a neurotransmitter,” “...exhibits quantum entanglement” are relatively recent predicates still earning their positions. The layer’s fluidity reflects ongoing inquiry at the research frontier.

Periphery: Observational and Episodic Predicates

At the outermost layer lie observational predicates tied to particular perceptual episodes: “...appears red to me now,” “...feels warm,” “...registers on this instrument.” These predicates activate episodically in specific contexts and have minimal dependencies—few other beliefs build on particular perceptual reports.

Peripheral predicates have minimal scope (highly contextualized), few dependencies, and low entrenchment. They’re the most revisable—if an observation seems anomalous, we readily question whether we perceived correctly, whether conditions were standard, whether instruments malfunctioned. Revising a perceptual report costs almost nothing beyond adjusting that specific belief.

Yet even perceptual predicates rest on Standing Predicates. “...appears red” presupposes concepts of color, perception, and phenomenal experience. “... registers on this instrument” presupposes instrumentation theory and causal interaction. The periphery connects to the core through these dependency chains, ensuring that even observational reports are theory-laden.

3.3 Dependency Relations Between Predicates

The layered organization reflects systematic presupposition relations. Many predicates presuppose others—they cannot be coherently applied without assuming background predicates are already in place. These dependency relations structure the architecture and constrain revision.

Consider “...is an infectious disease.” Applying this predicate presupposes:

- “...is a disease” (disease category exists)
- “...can be transmitted between organisms” (transmission concept)
- “...is caused by living agents” (biological causation)
- “...are organisms” (biological ontology)
- “...is alive” (life-nonlife distinction)
- “...exists in space and time” (material ontology)
- “...is subject to causal laws” (causation itself)
- “...is consistent with other beliefs” (logical coherence)

Each presupposed predicate belongs to a deeper layer. The specific (infectious disease) presupposes the general (disease), which presupposes biological categories, which presuppose material ontology, which presupposes logic.

Following presupposition chains always leads toward the core.

These dependencies are not merely conceptual but functional: you cannot deploy the dependent predicate without having the background predicates already operative. A physician diagnosing infectious disease must already be operating with biological categories, causal concepts, and logical inference. The dependencies track functional requirements for application.

The dependency structure explains why core predicates are hardest to revise. Revising “...is an infectious disease” requires updating medical theory. Revising “...is a disease” requires restructuring medicine entirely. Revising causation requires rebuilding all empirical science. Revising logic requires reconstructing all inquiry. Each deeper layer has exponentially more dependents, making revision exponentially more expensive.

Importantly, dependency relations emerged gradually rather than being designed. As new predicates proved useful, they naturally built on existing predicates rather than starting from scratch. “...is infectious” built on “...is a disease” because disease concepts were already validated. Over generations, this incremental building created the hierarchical dependency structure we now observe. The architecture is therefore historically contingent—different inquiry paths might have produced different intermediate layers—while convergence at the extremes (logic at core, observation at periphery) reflects functional necessities.

3.4 Computational Closure at Each Layer

Each architectural layer achieves computational closure through compression—the ability to reason productively at that level without constantly tracking lower-level

details. This closure is what makes layered organization functional rather than merely descriptive.

At the logical level, reasoning proceeds using inference rules without tracking neural implementations. You employ modus ponens without modeling synaptic firings that implement the inference. Logic provides closure for reasoning itself.

At the mathematical level, calculations proceed using axioms and theorems without tracking logical derivations of each theorem from axioms each time. You use the Pythagorean theorem without re-deriving it from Euclidean axioms. Mathematics provides closure for quantitative reasoning.

At the domain-general level (Tier 3), causal reasoning proceeds without tracking mathematical models of causation. You reason that striking the match caused ignition without solving differential equations for chemical reactions. Causation provides closure for explanation.

At the domain-specific level (Tier 4), medical diagnosis proceeds using disease categories without tracking molecular biology. You diagnose infection without modeling viral protein interactions. Disease categories provide closure for clinical reasoning.

At the periphery, observations are reported without tracking perceptual processing. You report seeing red without modeling retinal responses or neural encoding. Perceptual predicates provide closure for empirical reporting.

This multi-level closure is thermodynamically essential. Bounded cognitive systems cannot track all levels simultaneously—the computational costs would be prohibitive. By achieving closure at each level, the architecture enables efficient reasoning. When closure breaks down (anomalies leak through), the system must temporarily access lower levels to diagnose the problem, but most reasoning proceeds within a single level.

The closure at each level emerged through the same pragmatic filtering that created Standing Predicates. Predicates that enabled efficient reasoning without constant reference to lower levels were preferentially retained because they minimized cognitive costs. Predicates that required constant reference to implementation details were abandoned or refined until they achieved closure. The hierarchical architecture is therefore thermodynamically optimized—it's the solution to the problem of efficient reasoning under resource constraints.

In information-theoretic terms, each layer draws Markov blankets that statistically shield the layer from complexity above and below. Medical reasoning is shielded from molecular details by disease categories (downward blanket) and from sociological factors by clinical protocols (upward blanket). These blankets compress complexity while preserving prediction, enabling coarse-graining that maintains accuracy.

Failed predicates don't achieve computational closure—they leak information from other levels. Miasma theory leaked: it couldn't explain cholera transmission without constant ad hoc adjustments importing causal factors (water contamination) that didn't fit the theory. Phlogiston leaked: combustion phenomena kept revealing oxygen's role despite attempts to maintain phlogiston as the explanatory principle. High brittleness signals closure failure, indicating the predicate doesn't carve reality at genuine joints.

3.5 How Core Programs Achieved Their Position

The preceding subsections described the synchronic structure—how the architecture is currently organized. We now examine the diachronic process: how did core programs like logic achieve their foundational position? This emergence story is crucial for dissolving the apparent mystery of logical necessity while maintaining logic’s functional indispensability.

The Evolutionary Foundation

The deepest roots of logical structure lie not in human reasoning but in biological evolution. Long before explicit logical systems, organisms implemented proto-logical patterns in their behavioral repertoires. Consider a simple organism that has learned: if light, then food source. When light appears, the organism approaches. This behavior implements a conditional inference: if P, then Q; P; therefore Q. This is modus ponens at the behavioral level, though the organism has no explicit representation of the inference rule.

These proto-logical patterns succeeded because reality itself has structure. Causes reliably precede effects; contradictory properties don’t coexist; patterns persist across time. Organisms whose behavioral repertoires aligned with these structural regularities survived; those that violated them (approaching when predator-scent indicated danger, failing to track persistence of objects) were selected against.

Over evolutionary time, proto-logical patterns were refined and entrenched in neural architecture. Brains that implemented consistent inference rules outperformed those that reasoned inconsistently. The capacity for logical inference thus emerged through natural selection long before humans explicitly codified logical principles.

As organisms developed increasingly sophisticated cognitive capacities—internal models of their environment—selection pressure favored models exhibiting internal consistency. An organism whose model simultaneously represents “predator is present” and “predator is not present” cannot generate coherent action. The contradiction produces behavioral paralysis: if the predator is here, flee; if not here, forage. Contradictory beliefs yield contradictory imperatives, making coordinated response impossible. Selection thus eliminated cognitive architectures that tolerated contradiction, not because contradiction violates abstract logical laws, but because contradictory models disable effective action.

Similarly, organisms whose models failed to preserve valid inference patterns suffered fitness costs. If the model registers “all predators are dangerous” and “this is a predator” but fails to infer “this is dangerous,” the organism cannot utilize its stored knowledge effectively. Valid inference patterns became entrenched in cognitive architecture because they enable knowledge to guide behavior reliably. The proto-logical structure of inference rules—modus ponens, non-contradiction, transitivity—emerged as features of cognitive systems shaped by pragmatic success and failure over evolutionary timescales.

This testing is continuous across levels. Behavioral patterns that work are retained (behavioral level), cognitive architectures implementing these patterns are selected (cognitive level), and explicit codifications of these architectures prove successful in structuring inquiry (explicit level, discussed below). At each level, what “works” is determined by pragmatic consequences—survival, prediction, intervention—not by correspondence to abstract logical facts. Logic’s ultimate foundation is pragmatic: it works because it aligns with reality’s constraint structure.

The Cultural Codification

Humans inherited proto-logical capacities from evolutionary history but added crucial innovations: explicit formulation and systematic codification. Rather than just behaving logically, humans could articulate logical principles, evaluate them consciously, and teach them deliberately.

Early articulation was probably domain-specific. Practical reasoning in hunting, tracking, construction, and social coordination all employed logical inference implicitly. “If we see fresh tracks, the animal passed recently” involves conditional reasoning. “Either the fruit is ripe or it’s not” involves excluded middle. “You can’t be both here and at the river” involves non-contradiction. These patterns emerged independently across different practical contexts, suggesting they’re not culturally arbitrary but pragmatically necessary.

The crucial step was abstraction: recognizing that the same patterns applied across diverse domains. This recognition enabled explicit codification of logical principles as general rules rather than domain-specific heuristics. Ancient Greek logicians (notably Aristotle) performed this codification, articulating modus ponens, syllogistic reasoning, and laws of thought as universal principles.

Why did codification emerge? Efficiency and error-correction. Explicit logical principles enable teaching reasoning systematically rather than each person independently discovering patterns. They also enable detecting errors: when someone reasons invalidly, others can point to the violated logical rule. Codification thus served quality control, helping communities converge on reliable inference patterns.

Importantly, codification didn’t create logical principles—it recognized and systematized patterns that already operated implicitly. The success of explicit logic validated its alignment with the proto-logical patterns that evolution had already entrenched in cognition.

The Pragmatic Validation

Once explicitly formulated, logical principles underwent sustained pragmatic testing. Every successful use of logic—mathematical proof, scientific argument, practical reasoning—provided evidence for its reliability. Every attempt to violate logic—accepting contradictions, rejecting valid inferences—proved unsuccessful, generating confusion and error.

This pragmatic validation occurred across the broadest possible scope. Logic proved useful in mathematics, natural philosophy, law, rhetoric, theology, and everyday reasoning. The universality of its application across domains provided powerful evidence that logical principles weren’t just culturally contingent conventions but captured deep structural features of reality and reasoning.

Critical historical moments demonstrated logic’s robustness. When non-Euclidean geometry emerged, it seemed to threaten the necessary truth of mathematics—but the challenge was accommodated by recognizing that different geometric axioms generate different systems, all still governed by logic. When quantum mechanics raised puzzles about excluded middle and non-contradiction, these were addressed through refinements (quantum logic, complementarity) that preserved logical reasoning at the appropriate level. Even apparent challenges to logic reinforced its core status by requiring logic to adjudicate the challenges.

The Entrenchment Process

As logic proved universally useful, it underwent progressive entrenchment. Educational systems taught logic as fundamental; mathematical and scientific

inquiry presupposed it; philosophical discourse used it to evaluate arguments. With each generation, logic became more deeply embedded in intellectual infrastructure.

The entrenchment had economic logic: given logic's universal utility and perfect track record, constantly re-evaluating it would waste cognitive resources. By caching logical principles as background assumptions, inquiry could focus on domain-specific questions rather than perpetually re-litigating inference rules. This caching enabled cumulative knowledge—each generation builds on logical infrastructure established by predecessors.

Crucially, entrenchment doesn't mean blind acceptance. The logical principles that became entrenched were those that continued proving useful under sustained application. Alternative logics (many-valued, paraconsistent, intuitionistic) were explored when specific contexts suggested them, and some found specialized applications. But classical logic maintained its core position because it continued functioning successfully across the broadest scope.

Achieving Core Status

Through this multi-stage process—evolutionary foundation, cultural codification, pragmatic validation, and entrenchment—logical principles migrated to the network's core. They achieved the position of constantly-active, universally-presupposed, functionally-unrevisable programs that structure all inquiry.

This core status reflects accumulated pragmatic success, not metaphysical necessity. Logic occupies the core because:

1. **Evolutionary timescale:** Billions of years of selection pressure on organisms
2. **Universal scope:** Applies across all domains without exception
3. **Maximal dependencies:** All inquiry presupposes logical inference
4. **Perfect track record:** No viable alternatives have emerged despite sustained exploration
5. **Prohibitive revision costs:** Re-deriving all dependent structures would require rebuilding all knowledge

For bounded agents operating within this accumulated history, logic is functionally unrevisable even though it's not metaphysically necessary. To question logic requires using logic, creating pragmatic circularity that locks it in place. This isn't vicious circularity but structural consequence of logic's role as the operating system for inquiry.

The emergence story thus dissolves the mystery while preserving the phenomenon. Logic feels necessary because it's maximally entrenched, but it earned that entrenchment through the same pragmatic filtering that operates throughout the network. The difference is one of degree—timescale, scope, and dependencies—not fundamental kind. Logic is the endpoint of Standing Predicate emergence operating at maximum scale.

Understanding how core programs achieved their position illuminates both the architecture's structure and its genesis. The layered organization we observe today emerged gradually through pragmatic filtering, with successful predicates migrating toward the core while failed ones were abandoned. The next section examines how this architecture functions dynamically, with predicates activating differentially in response to experience.

4. Activation Dynamics: Responding to Recalcitrant Experience

The layered architecture described in Section 3 is not static but dynamically responsive to experience. Different predicates activate in response to different challenges, creating patterns of differential activation that both reflect and reinforce the architectural hierarchy. This section explicates these activation dynamics, showing how the web responds to anomalous experience and why core predicates like logic remain constantly active.

4.1 What is Recalcitrant Experience?

Quine introduced “recalcitrant experience” to describe observations that conflict with a belief system’s predictions (Quine 1960). When experience contradicts expectations, the system faces pressure to revise—but which beliefs should change? Quine’s insight was that no single belief is uniquely responsible; the entire connected web is implicated, and revision can occur anywhere within it, guided by pragmatic considerations.

We extend this individual-level concept to knowledge systems. Recalcitrant experience manifests as accumulated costs when network principles meet reality: failed predictions, ineffective interventions, mounting anomalies requiring ad hoc explanations, increasing complexity without corresponding explanatory gain. These costs signal misalignment between the network’s conceptual structure and reality’s constraint structure.

Recalcitrant experience comes in degrees. Minor anomalies are routine—an unexpected lab result, an instrument malfunction, an observation slightly off from predictions. These generate local brittleness requiring minor adjustments: check the instrument calibration, run the experiment again, refine the measurement technique. The network absorbs these perturbations through peripheral adjustments without disturbing the core.

Moderate anomalies accumulate when systematic patterns emerge. Multiple labs report similar discrepancies; different experimental approaches yield consistent contradictions; phenomena resist explanation despite repeated attempts. The brittleness migrates inward—peripheral adjustments prove insufficient, and domain-specific theoretical frameworks require reconsideration. This triggers broader activation patterns as deeper predicates are brought into question.

Severe crises arise when anomalies resist resolution despite sustained effort, forcing reconsideration of fundamental principles. The brittleness penetrates to near-core levels, threatening domain-general frameworks. Historical examples include the luminiferous ether crisis in physics, the phlogiston crisis in chemistry, and the miasma crisis in medicine. These crises demanded fundamental reconceptualization, activating predicates across multiple tiers.

The severity of recalcitrant experience thus determines activation depth: which layers of the architecture are brought into conscious evaluation versus which remain operative as background assumptions. This creates differential activation patterns corresponding to different crisis types.

4.2 Selective Activation Patterns

The architecture responds to recalcitrant experience through selective activation—different predicates are brought into conscious evaluation depending on the nature and severity of the challenge. This section traces three paradigmatic patterns.

Pattern 1: Peripheral Anomaly (Minimal Activation)

Consider a routine laboratory experiment yielding an unexpected result. A chemist measuring reaction rates obtains a value significantly divergent from theoretical predictions. This peripheral anomaly activates only the outermost layers:

Activated predicates: - Observational: “...registered on this instrument,” “...under these conditions” - Experimental protocol: “...was properly calibrated,” “...followed standard procedure” - Local theoretical context: “...should yield this reaction rate under these conditions”

Dormant predicates: - Chemistry Standing Predicates: “...is an acid,” “...reacts exothermically” (presumed correct) - General causal framework: “...obeys conservation laws” (not questioned) - Logic: “...follows by modus ponens” (operates implicitly)

The response is localized: check instruments, verify conditions, repeat the experiment. The chemist doesn't question whether acids behave as acids or whether causal laws operate—only whether this particular measurement was accurate. Core predicates remain dormant, functioning as unquestioned background.

This pattern is most common in normal science. Daily research encounters peripheral anomalies constantly, but the vast majority are resolved through local adjustments. The architecture's efficiency lies precisely in this localization: bounded agents can focus cognitive resources on the immediate anomaly without activating the entire network.

Pattern 2: Domain-Specific Crisis (Moderate Activation)

Now consider a systematic challenge to domain-specific theory. In the 19th century, phlogiston theory faced mounting anomalies: metals gained weight when burned (contrary to phlogiston release), combustion required air (unexplained by phlogiston), various substances showed conflicting phlogiston contents. These weren't isolated experimental errors but systematic patterns demanding theoretical reconsideration.

Activated predicates: - Domain-specific Standing Predicates: “...contains phlogiston,” “...is released during combustion” - Alternative frameworks: “...combines with oxygen,” “...is an oxidation reaction” - Chemical ontology: What are the fundamental substances? What are chemical reactions? - Experimental methodology: How do we test these competing frameworks?

Dormant predicates: - General causal framework: “...obeys conservation laws” (operational but not questioned) - Material ontology: “...is matter,” “...has mass” (presumed) - Logic: “...contradicts,” “...follows from” (employed but not examined)

The activation extends deeper than peripheral adjustments but stops short of fundamental frameworks. Chemists questioned phlogiston but not whether matter exists or whether logic applies. They used logical inference to evaluate competing

theories, used conservation principles to test predictions, but didn't question these deeper commitments.

Resolution required reconceptualizing chemistry's conceptual architecture—replacing phlogiston with oxygen, reinterpreting combustion as oxidation—but the general frameworks of causation, material ontology, and logical inference remained operational throughout. The crisis was contained to Tier 4 (domain-specific) and partially Tier 3 (chemical ontology), while Tiers 2 and 1 remained unactivated.

Pattern 3: Deep Conceptual Crisis (Extensive Activation)

Rare but transformative crises penetrate to near-core levels. Quantum mechanics in the early 20th century generated such a crisis. Paradoxes like wave-particle duality, the measurement problem, and quantum entanglement resisted resolution through domain-specific adjustments, forcing reconsideration of fundamental concepts.

Activated predicates: - Physics Standing Predicates: "...is a particle," "...is a wave," "...has definite position" - Physical ontology: What are the fundamental entities? What is measurement? - Causation: "...determines," "...causes" (reexamined: indeterminism, nonlocality) - Even logic: "...satisfies excluded middle," "...is determinate" (questioned: complementarity, superposition)

Still dormant: - Core logic: Modus ponens, non-contradiction (used to evaluate alternatives, not questioned)

The activation extended extraordinarily deep—physicists questioned causation, determinism, and even whether physical systems have definite properties before measurement. Some explored alternative logics (quantum logic, paraconsistent approaches). Yet even here, absolute core logic remained operative: physicists used modus ponens to derive consequences of quantum theory, employed non-contradiction to eliminate inconsistent interpretations, and reasoned logically about whether logic itself required modification.

This pattern reveals the limit of activation: even the deepest crises in empirical science leave Tier 1 logic functioning as the operating system for evaluating alternatives. Logic isn't immune to question—physicists and philosophers actively considered logical revisions—but it remains operationally presupposed even when being questioned. This is the signature of genuine core status.

4.3 Why Some Beliefs Are Always Active

The activation patterns reveal an asymmetry: while peripheral and intermediate predicates activate contextually in response to specific challenges, core predicates remain constantly active across all inquiry. Logic operates continuously—you cannot investigate chemistry, evaluate theories, or even question logic itself without employing logical inference. Why this asymmetry?

The straightforward answer is functional role: logic provides the inferential machinery for all reasoning, so any reasoning activity employs it. But this answer invites a deeper question: why does logic play this unique functional role? Why can't we sometimes "turn off" logic and reason differently, as we can turn off chemistry knowledge when investigating history?

Three factors explain logic's constant activation. First, universality of scope: logic applies across all domains without exception. Every inquiry—empirical, mathematical, philosophical, practical—employs logical inference. There is no

domain where logic is irrelevant, unlike domain-specific predicates that activate only in their specialized contexts.

Second, dependency structure: all inquiry presupposes logical inference. You cannot evaluate evidence without modus ponens, cannot identify contradictions without non-contradiction, cannot reason about alternatives without disjunctive syllogism. Even questioning logic requires using logic—creating pragmatic circularity that makes logic simultaneously indispensable and untestable within the system.

Third, lack of alternatives: no viable alternative to logic has emerged despite extensive exploration. Alternative logics (paraconsistent, many-valued, intuitionistic) have been developed for specialized contexts, but none has displaced classical logic as the general framework. Each alternative logic is evaluated using classical logical reasoning, reinforcing its foundational status.

These factors compound: logic has universal scope because all inquiry needs inference rules, all inquiry presupposes logic because it has universal scope, and no alternatives emerged because logic works so well across this universal scope. The circularity isn't vicious but reinforcing—logic's success created dependencies that made it more entrenched, which made it harder to replace, which demonstrated its reliability, which justified further dependence.

But these are synchronic explanations—they describe logic's current functional role without explaining how logic achieved that role. For the full story, we need the diachronic perspective.

4.4 Why Logic Stays Active: The Emergence Perspective

From the emergence perspective developed in Section 3.5, logic's constant activation reflects accumulated pragmatic success over the longest timescale. Logic isn't constantly active because it's metaphysically necessary or a priori; it's constantly active because it has proven maximally useful across maximal scope over maximal time, creating maximal dependencies that make it functionally unrevisable for bounded agents.

The Evolutionary Accumulation

Proto-logical patterns proved successful over billions of years of evolutionary history. Every organism that survived to reproduce demonstrated rudimentary logical inference: if danger-signal, avoid; if food-signal, approach; if action-A led to outcome-B previously, expect B when doing A. Organisms violating these patterns—approaching danger, ignoring food, failing to learn from experience—were systematically selected against.

This vast timescale created deep entrenchment. By the time humans evolved explicit reasoning, logical structure was already profoundly embedded in neural architecture. Our brains implement logical inference not because we consciously chose it but because billions of years of selection pressure refined cognitive systems toward logical structure. Logic feels “natural” and “necessary” because it's neurally entrenched, not because it's metaphysically privileged.

The Historical Validation

Once humans could explicitly formulate logical principles, every subsequent successful inquiry provided further validation. Mathematics developed as a formal logical system, achieving spectacular success. Natural philosophy (later science) employed logical argumentation, generating increasingly accurate theories. Legal

reasoning, ethical deliberation, practical planning—every domain where logic was systematically applied yielded successful results.

This historical accumulation is asymmetric with respect to failures: failed logical reasoning generated costs that forced revision (correcting logical errors, eliminating contradictions), while successful logical reasoning enabled cumulative progress (building proofs, deriving theorems, testing theories). Over millennia, this asymmetry drove progressive entrenchment—logic kept working, alternatives kept failing, and dependencies deepened.

Critical historical junctures tested logic's robustness. Non-Euclidean geometry showed mathematical axioms weren't necessary, but geometry still required logical inference. Quantum mechanics raised paradoxes about classical logic, but physicists used logic to explore alternatives. Every apparent challenge was ultimately accommodated while preserving logic's core role. This track record of surviving challenges while enabling progress created justified confidence in logic's reliability.

The Dependency Accumulation

As inquiry progressed, more knowledge structures built on logical foundations. Mathematics presupposes logic; science presupposes mathematics; technology presupposes science; civilization presupposes technology. Each layer added dependencies, creating a vast pyramid with logic at the base.

These dependencies have thermodynamic significance: revising logic would require re-deriving everything that depends on it. The computational cost grows exponentially with dependencies. For contemporary knowledge systems, the cost of revising logic is effectively infinite—we would need to rebuild mathematics, science, technology, and all theoretical frameworks from scratch.

For bounded agents with finite cognitive resources, infinite revision costs create functional unrevisability. It's not that logic cannot be revised in principle (we can imagine alternative logical systems), but that actually revising logic would exceed available resources. The pragmatic impossibility creates experienced necessity: logic feels necessary because for us, with our history and dependencies, it is functionally necessary.

Why Logic Stays Constantly Active

Given this accumulated history—evolutionary entrenchment, historical validation, and dependency accumulation—logic remains constantly active because deactivating it has prohibitive costs. When investigating chemistry, we can “turn off” biological knowledge because biological predicates aren't presupposed by chemistry. But we cannot turn off logic because chemistry presupposes logical inference. Chemical theory is built using logical derivation, chemical experiments are evaluated using logical argumentation, and chemical anomalies are adjudicated using logical consistency.

The constant activation is therefore a

consequence of architecture, not an intrinsic property of logic. Logic remains active not because of what logic is (abstract necessary truths) but because of where logic is (the foundation layer supporting all other inquiry after billions of years of entrenchment). Different histories might have produced different cognitive architectures—but given our actual history, logic's constant activation reflects its earned position as the operating system.

This dissolves the mystery while preserving the phenomenon. Logic is constantly active across all domains because it has proven maximally successful over

maximal scope and timescale, creating maximal dependencies that make deactivation functionally impossible for bounded agents. The “necessity” we experience is pragmatic lock-in, not metaphysical privilege.

4.5 The Cost Landscape of Revision

The activation patterns reflect an underlying cost landscape—the distribution of revision costs across the architecture. Understanding this landscape explains which predicates activate in response to which challenges and why activation depth corresponds to crisis severity.

Two Dimensions of Cost

Every predicate has two relevant costs: brittleness cost (maintaining the predicate given its misalignment with reality) and revision cost (changing the predicate given its dependencies and entrenchment). The rational response to recalcitrant experience minimizes total cost.

Brittleness cost measures misalignment: how much conceptual debt, failed prediction, ineffective intervention, and ad hoc patching the predicate generates. A predicate perfectly aligned with reality has zero brittleness cost—it enables successful prediction and intervention without requiring patches. A predicate misaligned with reality accumulates brittleness—each application generates surprises requiring explanation, interventions fail, and the system must constantly adjust to accommodate discrepancies.

Revision cost measures disruption: how much re-derivation, re-learning, and restructuring changing the predicate requires. A peripheral predicate with few dependents has low revision cost—changing it affects little else. A core predicate with vast dependents has enormous revision cost—changing it requires rebuilding all structures that presuppose it.

The cost landscape creates a gradient from periphery to core. Peripheral predicates typically have high brittleness potential (they’re closely tied to observations that can easily contradict them) but low revision costs (few dependents). Core predicates have low brittleness (they’ve been validated across maximal scope) but astronomical revision costs (vast dependents).

Localization of Response

Rational response to recalcitrant experience follows a pragmatic principle: revise at the level where total cost (brittleness + revision) is minimized. This typically means revising peripherally unless peripheral revisions prove insufficient.

When an experiment yields anomalous results, we first question the observation itself (zero revision cost—just repeat the experiment). If the anomaly persists, we question local theory (low revision cost—adjust parameters or auxiliary hypotheses). Only if anomalies accumulate systematically do we question domain-specific frameworks (moderate revision cost). And only if crises persist despite domain-specific revisions do we question fundamental principles (high revision cost).

This creates the observed activation patterns: peripheral challenges activate peripheral predicates, domain crises activate domain frameworks, and only deep crises activate near-core principles. The architecture localizes response to minimize costs, activating only as deeply as necessary to restore coherence.

The Logic Case

Logic occupies a unique position in the cost landscape: near-zero brittleness (perfect track record across all domains over maximal time) combined with effectively infinite revision cost (all inquiry presupposes it). This creates functional unrevisability—any alternative would require astronomical disruption while logic itself generates no brittleness pressure for revision.

This isn't mere conservatism. If logic generated significant brittleness—if logical reasoning systematically failed, if contradictions proved useful, if modus ponens led to false conclusions—then despite high revision costs, we would face pressure to revise. The history of science shows we do revise high-cost principles when brittleness accumulates sufficiently (Newtonian mechanics, Euclidean geometry, determinism).

But logic generates no such pressure. Every application of logical inference succeeds; every violation of logic generates confusion; every attempted alternative either reduces to classical logic for its domain or proves unworkable for general use. Zero brittleness combined with infinite revision cost creates stable equilibrium—no pressure for change and overwhelming cost if change were attempted.

This explains why logic remains constantly active while being theoretically revisable. In principle, we could adopt alternative logics. In practice, the cost-benefit analysis overwhelmingly favors retaining classical logic for general reasoning. The “in principle” possibility preserves fallibilism; the “in practice” impossibility explains experienced necessity.

Implications for Truth

The cost landscape illuminates how truth emerges from architecture. Predicates migrate toward truth not by coming to correspond with abstract facts but by finding stable positions in the cost landscape where brittleness is minimized and revision becomes progressively more costly due to accumulating dependencies.

Truth at Level 1 (objective truth) represents the attractor points in this landscape—configurations that minimize total cost across all possible inquiry paths. Logic occupies such an attractor: it generates zero brittleness while supporting all other inquiry, making it the optimal foundation for any knowledge system operating under resource constraints. That multiple independent inquiry traditions converged on logic validates its status as an objective attractor, not merely a local optimum for our particular history.

The architecture thus transforms truth from a metaphysical puzzle into a thermodynamic achievement: truth is what remains when pragmatic filtering eliminates high-brittleness configurations while entrenchment locks in low-brittleness solutions. Logic's truth is its proven position as the minimal-cost foundation for inquiry, validated through maximal scope and timescale.

5. Functional Transformation: How Predicates Become Truth

Having examined the architecture's structure and activation dynamics, we now detail the mechanism of functional transformation—the process by which predicates migrate from tentative hypotheses to core infrastructure. This

transformation is how beliefs become truth: not by coming to correspond with abstract facts but by achieving certain functional positions within the architecture through sustained pragmatic success. Logic's path through this transformation serves as the paradigmatic case, demonstrating that even our most foundational "truths" emerged through naturalistic processes.

5.1 The Five-Stage Progression

The general mechanism of functional transformation proceeds through five stages, though boundaries between stages are porous and not every predicate completes the entire progression. The stages track increasing entrenchment, expanding dependencies, and deepening functional role.

Stage 1: Initial Hypothesis (Being-Tested)

A predicate enters the system as a tentative proposal—a candidate explanation, categorization, or inference rule that might prove useful. At this stage, the predicate is being-tested: it's data under evaluation, not yet a tool for evaluating other claims. Scientists propose "...is caused by a virus" for a novel disease; mathematicians propose "...satisfies this axiom system" for a new geometry; philosophers propose "...follows by this inference rule" for systematic reasoning.

The predicate at Stage 1 has minimal entrenchment (newly introduced), few dependencies (nothing yet builds on it), narrow scope (applies to specific contexts), and high epistemic uncertainty (might be wrong). It competes with alternatives and faces potential refutation. Most predicates remain at or near this stage—they're tested, found wanting, and either refined or abandoned.

Stage 2: Validated Data (Locally Proven)

Through repeated application across specific contexts, some predicates demonstrate reliability. They successfully predict outcomes, enable effective interventions, and integrate coherently with existing knowledge. The predicate earns initial trust within its domain—it's no longer merely hypothetical but validated within a circumscribed range.

Stage 2 predicates have moderate entrenchment (established within subdomain), local dependencies (some domain-specific beliefs build on them), demonstrated scope (successful across multiple specific applications), and reduced uncertainty (repeatedly confirmed). The predicate remains subject to revision but has earned provisional acceptance. "...is caused by a virus" becomes established for certain diseases after extensive epidemiological and laboratory work.

Stage 3: Standing Predicate (Tool-That-Tests)

The crucial transformation occurs when a predicate's status changes from tested-data to tool-that-tests. Rather than being evaluated against alternatives, the predicate becomes part of the evaluative framework itself—a diagnostic category, an explanatory principle, a reasoning tool that structures inquiry within its domain.

When a physician encounters a novel respiratory illness, "...is caused by a virus" isn't a hypothesis they test alongside bacterial or fungal causes (though they'll determine which virus). It's a diagnostic framework they apply to structure investigation: identify the viral pathogen, trace transmission routes, prescribe antiviral treatments if available, implement infection control. The predicate unpacks a suite of proven methods rather than making a claim under scrutiny.

Standing Predicates have significant entrenchment (widely taught and applied), substantial dependencies (domain theories build on them), proven scope (successful across diverse contexts within domain), and practical certainty for domain purposes (reliable enough to guide action). The transformation is functional: the predicate's role in reasoning has changed from that which is questioned to that which does the questioning.

Stage 4: Convergent Core Entry (Functionally Unrevisable)

For predicates with sufficiently broad success and deep dependencies, a further shift occurs: migration to the convergent core of their domain. These predicates become so foundational that alternatives are relegated to a Negative Canon of abandoned approaches. Questioning them requires extraordinary evidence because vast knowledge structures depend on them.

Germ theory occupies this position in medicine. While technically revisable, abandoning germ theory would require rebuilding medicine from scratch. The cost is prohibitive without overwhelming evidence, making the predicate functionally unrevisable. Core predicates are maximally entrenched within their domain, create vast dependencies, demonstrate universal scope within the domain, and are pragmatically certain (treated as reliable for all practical purposes).

Stage 5: Hard Core (Constitutive of Inquiry)

The final stage, reached by few predicates, is the hard core: principles so fundamental that their removal would collapse the entire edifice of inquiry. These predicates aren't just central to a domain but constitutive of inquiry itself—removing them eliminates the conditions for asking questions and evaluating answers.

Logic occupies this ultimate position. Logical predicates like "...follows by modus ponens," "...is a contradiction," "...is consistent with" structure all reasoning regardless of domain. They cannot be questioned without being employed, creating pragmatic circularity that locks them in place. Hard core predicates are maximally entrenched across all inquiry, create universal dependencies, demonstrate universal scope, and are functionally necessary (cannot be deactivated without system collapse).

The five stages thus track a progression from hypothesis to infrastructure, from data to operating system, from tested to tool-that-tests. Truth emerges through this progression: predicates become true by migrating through these stages via sustained pragmatic validation.

5.2 Logic's Path Through the Five Stages

Logic's journey through these stages spans the longest timescale and widest scope of any predicate system. Tracing this journey demonstrates that even logic—paradigm of necessary, *a priori* truth—achieved its foundational status through pragmatic filtering, not metaphysical privilege.

Pre-Stage 1: Proto-Logical Behavioral Patterns (Evolutionary Foundations)

Before logic was explicitly formulated, proto-logical patterns operated in biological organisms. These weren't conscious inference rules but behavioral regularities implementing logical structure. Consider a predator-prey relationship: if organism detects predator-signal, then organism exhibits fleeing behavior.

When predator-signal appears, fleeing occurs. This implements modus ponens behaviorally: if P, then Q; P; therefore Q.

These proto-logical patterns succeeded because they aligned with environmental regularities. Causes typically precede effects; objects persist through time; contradictory properties don't coexist simultaneously. Organisms whose behavioral patterns tracked these regularities survived; those violating them faced selection pressure.

Natural selection thus “tested” proto-logical patterns over billions of years. Not through explicit evaluation—organisms don’t consciously reason about inference rules—but through differential reproductive success. Organisms implementing consistent inference patterns (approach food, avoid danger, track object persistence) outperformed those with inconsistent patterns (randomly approaching danger, losing track of objects, failing to learn regularities).

Over evolutionary time, proto-logical structure became deeply embedded in neural architecture. Brains evolved connection patterns that naturally implement logical inference: pattern detection (if A co-occurs with B repeatedly, expect B when A appears), consistency maintenance (don’t simultaneously approach and avoid the same stimulus), and transitivity tracking (if A leads to B and B leads to C, connect A to C). These neural implementations provide the biological foundation for explicit logical reasoning.

Stage 1: Early Explicit Formulation (Being-Tested)

With human evolution came the capacity to explicitly formulate principles that had previously operated implicitly. Early humans could articulate rules rather than just following them: “If we see smoke, there is fire.” “Either the animal went left or right; it didn’t go right; so it went left.” “If you’re here, you can’t also be there.”

These early formulations occurred in practical contexts—tracking prey, planning hunts, coordinating group activities, resolving disputes. The rules weren’t abstract logical principles but domain-specific heuristics that happened to instantiate logical structure. They were being-tested through application: do these rules help us reason successfully? Do they enable effective prediction and coordination?

The testing occurred implicitly through success and failure. Hunters reasoning logically (following tracks consistently, eliminating impossible routes, inferring unseen elements) succeeded more often than those reasoning inconsistently. Communities establishing logical consistency in their narratives and norms coordinated more effectively. The pragmatic pressure wasn’t formalized, but it was real—logical reasoning worked better than its alternatives.

Crucially, alternatives were implicitly tried and failed. Reasoning that accepted contradictions generated confusion and coordination failures. Reasoning that ignored valid inferences missed important implications. Reasoning that violated consistency led to practical difficulties. These failures created selection pressure toward logical patterns, though the selection occurred through accumulated practical consequences rather than explicit evaluation.

Stage 2: Systematic Codification (Locally Proven)

A major transition occurred when ancient philosophers—particularly Greek logicians like Aristotle—explicitly codified logical principles as general rules. Rather than domain-specific heuristics, these were abstracted principles claimed

to apply universally: the law of non-contradiction, the law of excluded middle, syllogistic forms, rules of inference.

Why did systematic codification emerge? Efficiency and quality control. Explicit logical principles enable systematic teaching—rather than each person independently discovering inference patterns through trial and error, communities can transmit proven principles. Codification also enables error detection: when someone reasons invalidly, others can identify which logical rule was violated and correct the error.

The codified principles were validated within circumscribed contexts initially—mathematical proof, philosophical argument, legal reasoning, rhetorical persuasion. In each domain, logical inference proved successful: mathematical proofs using syllogistic reasoning yielded correct results; philosophical arguments following logical structure compelled assent; legal reasoning applying consistent principles enabled fair adjudication.

This validation was local rather than universal—logic was proven effective within intellectual domains but hadn't yet permeated all inquiry. Many practical activities (agriculture, craft production, medicine) proceeded without explicit logical codification. The predicates were Stage 2: validated within their domains, beginning to be entrenched, but not yet universal tools.

Stage 3: Functional Transformation (Tool-That-Tests)

Over subsequent centuries, a crucial transformation occurred: logic shifted from being a system under evaluation to being the framework for evaluation itself. Rather than testing whether logical inference works, thinkers used logical inference to test other claims. Logic became the tool-that-tests rather than data-being-tested.

This transformation manifested across domains. Mathematics became explicitly logical—the goal was proving theorems from axioms using valid inference. Natural philosophy adopted logical argumentation—theories were evaluated based on whether they followed logically from evidence and principles. Theology used logical analysis to evaluate doctrines. By the medieval period in Western philosophy, logic occupied a foundational role: it was among the first subjects taught because all other subjects presupposed logical reasoning.

The functional transformation had cognitive significance: logic no longer competed with alternatives but provided the framework for evaluating alternatives. When someone proposed a new theory, the question wasn't "Should we use logic to evaluate this?" but "Does this theory satisfy logical standards?" Logic had become infrastructure for inquiry itself.

Alternative "logics" that violated standard principles—accepting contradictions, rejecting excluded middle, ignoring valid inferences—were systematically tried through history and failed. Contradiction-accepting reasoning proved unworkable (if everything is both true and false, no distinction can be maintained). Systems violating excluded middle for non-constructive domains faced practical difficulties. Every attempted alternative either reduced to standard logic for most purposes or proved unworkable for general reasoning.

This track record of alternatives failing while standard logic succeeded drove progressive entrenchment. Logic wasn't merely validated; it was proven uniquely successful. The functional transformation was thus justified: logic earned its status as tool-that-tests through outcompeting all alternatives across the widest range.

Stage 4-5: Migration to Absolute Core (Functionally Unrevisable)

By the modern period, logic had achieved maximal core status. It's not merely foundational within domains (as germ theory is foundational in medicine) but foundational for all inquiry. No domain exists where logic is dispensable. Mathematics, science, philosophy, law, engineering, medicine, history—every field presupposes logical inference. Even questioning logic requires using logic.

This creates pragmatic circularity distinguishing core logic from domain-specific foundations. You can question germ theory without using germ theory—you can investigate disease using other frameworks. But you cannot question modus ponens without employing modus ponens: “If questioning modus ponens requires reasoning, and questioning modus ponens is reasoning, then questioning modus ponens requires modus ponens.” The circularity isn’t vicious—it reveals logic’s role as operating system rather than application software.

The dependencies created by this history are now astronomical. All mathematical proofs presuppose logic; all scientific theories are evaluated logically; all technological systems are designed using logical inference; all institutions coordinate using logical consistency. Revising logic would require re-deriving every dependent structure—effectively rebuilding all systematic knowledge from scratch.

For bounded agents, this creates functional unrevisability. Not metaphysical impossibility—we can imagine alternative logics—but practical impossibility given finite resources and accumulated dependencies. The revision cost is infinite; the brittleness cost is zero (logic continues working perfectly across all domains). This cost structure locks logic in place.

Logic thus reached Stage 5: the hard core of constitutive principles. Not because of what logic is (abstract necessary truths) but because of where logic is (the foundational layer after billions of years of pragmatic filtering). The position was earned through the longest validation track record across the widest scope, creating maximal dependencies that make logic simultaneously indispensable and untestable.

The Significance of the Journey

Tracing logic’s journey through the five stages accomplishes two goals. First, it demonstrates radical naturalism: even logic—paradigm of *a priori* necessity—emerged through pragmatic validation and functional transformation. There’s no metaphysical rupture between logical and empirical knowledge; both occupy positions on the same continuum, distinguished by degree of entrenchment and scope rather than kind of justification.

Second, it dissolves the mystery while preserving the phenomenon. Logic feels necessary, unrevisable, and foundational—and it is, given our history and architecture. But this necessity is pragmatic, not metaphysical. Different evolutionary histories might have produced cognitive architectures with different core structures (though convergent evolution suggests logic represents an objective attractor). The necessity we experience reflects logic’s earned position, not its intrinsic nature.

5.3 Three Levels of Truth

The functional transformation mechanism generates multiple levels at which “truth” can be attributed, corresponding to different degrees of validation and

architectural position. Understanding these levels clarifies what we mean when we call a predicate “true” and how truth relates to functional role.

Level 3: Contextual Coherence

At the most minimal level, a predicate is “true” (or better, truth-apt) when it coheres with other propositions within some knowledge system. This is internal consistency without necessary viability. Fictional systems like Sherlock Holmes stories, abandoned scientific theories like phlogiston chemistry, and internally consistent but empirically false frameworks all achieve Level 3 truth: their predicates cohere with each other and enable consistent reasoning within the system.

Level 3 truth explains how non-viable systems can feel coherent to participants. A Ptolemaic astronomer could reason consistently within their framework, a phlogiston chemist could make predictions that sometimes succeeded, a flat-Earth believer can construct coherent (if elaborate) explanations for observations. The internal coherence isn’t evidence of truth in deeper senses, but it’s not meaningless—it indicates the system has achieved minimal logical organization.

This level corresponds to Stage 1-2 in functional transformation: predicates that cohere within a framework but haven’t been extensively tested against reality. They might turn out to be true at deeper levels, or they might be abandoned as brittleness accumulates.

Level 2: Justified Truth (Low-Brittleness Certification)

When predicates maintain coherence under sustained pragmatic testing, they earn Level 2 truth: justified truth or pragmatic truth. These predicates are certified by low-brittleness networks that demonstrate viability through successful application. Germ theory in medicine, evolutionary theory in biology, thermodynamics in physics occupy this level—they’re what we rationally believe to be true given extensive validation.

Level 2 truth is deflationary regarding correspondence but substantive regarding validation. Saying “germ theory is true” doesn’t claim it mirrors abstract facts but registers that it’s certified by viable medical networks demonstrating consistent success. The truth-attribution tracks functional role: germ theory occupies a position in medical architecture that enables successful diagnosis, treatment, and research.

This level corresponds to Stages 3-4 in functional transformation: Standing Predicates that have proven their reliability and achieved significant entrenchment. Level 2 predicates remain fallible—future evidence might force revision—but they’re justified given current evidence. This is the level occupied by most Standing Predicates in mature sciences.

Level 1: Objective Truth (Apex Network Alignment)

The highest level is objective truth: alignment with the constraint-determined structure that multiple independent inquiry paths converge upon. This is what we take to be true not just for us but for any knowledge system operating under the same constraints. Logic, basic thermodynamics, fundamental mathematics, and perhaps a few other maximally validated principles occupy this level.

Level 1 truth combines deflationary metaphysics with convergent realism. Deflationarily, there’s no correspondence to Platonic forms. But realistically, the convergence of independent inquiry traditions on the same structures indicates these aren’t culturally arbitrary or historically contingent—they represent objective attractors in the space of viable knowledge configurations.

That ancient Greek logic, classical Indian logic, Chinese logic, and modern formal systems independently developed essentially similar core principles suggests logic occupies an objective attractor point. Any learning system must implement logical structure to succeed; reality's constraint structure forces convergence on logical inference. This is objective not in the sense of corresponding to abstract objects but in the sense of being constraint-determined.

This level corresponds to Stage 5: hard core predicates that have survived maximal testing across maximal scope, accumulated maximal dependencies, and proven irreplaceable. Level 1 predicates are fallible in principle (we can imagine being wrong about them) but functionally unrevisable in practice (revising them exceeds available resources).

The Relationship Between Levels

The three levels form a nested hierarchy: Level 1 predicates are also Level 2 and Level 3; Level 2 predicates are also Level 3; but the reverse doesn't hold. All objectively true predicates are justified and coherent, but not all coherent predicates are justified, and not all justified predicates are objective.

The nesting reflects the functional transformation process: predicates progress from coherence to justification to objectivity through sustained validation. Most predicates remain at Level 3 (coherent within some system but not extensively tested). Many reach Level 2 (validated within viable networks). Very few reach Level 1 (proven across all inquiry and converged upon independently).

Truth at each level is deflationary regarding metaphysics but substantive regarding functional role. "Is true" doesn't denote a special property but tracks architectural position and validation degree. Yet this tracking is non-arbitrary: positions reflect accumulated pragmatic success, and higher levels indicate more extensive validation across wider scope.

5.4 Programs as Conceptual Technology

Standing Predicates function as conceptual technology—Reusable programs that compress successful practices into efficient tools. Understanding this technological dimension clarifies how predicates enable cumulative knowledge and why entrenchment serves cognitive efficiency.

A Standing Predicate like "...is an infectious disease" is a program: it takes an input (a novel illness), applies compressed diagnostic and therapeutic patterns (isolate the patient, identify the pathogen, trace transmission, implement sterilization), and generates reliable outputs (effective containment and treatment). The predicate packages generations of accumulated experience into a single, efficiently deployable tool.

This program structure enables cognitive efficiency. Without Standing Predicates, each generation would rediscover basic principles from scratch. With Standing Predicates, each generation inherits proven tools and builds on them. Medical students learn "...is infectious" as a foundational category, then specialize in particular infectious diseases. They don't re-derive germ theory but deploy it as infrastructure for more advanced learning.

The efficiency has thermodynamic significance: caching proven patterns minimizes cognitive costs. Just as computers cache frequently-used calculations rather than recomputing them each time, knowledge systems cache proven predicates as Standing infrastructure. This is not intellectually lazy but thermodynamically

optimal—bounded agents cannot afford to constantly re-evaluate well-established principles.

Standing Predicates thus embody cultural-epistemic evolution. They’re the “genes” of knowledge systems—units of information that replicate across generations with variation and selection. Successful predicates replicate (taught, applied, transmitted); unsuccessful predicates are eliminated (abandoned, forgotten, relegated to negative canon). The accumulated library of Standing Predicates represents the survivors of sustained pragmatic selection.

Logic represents the ultimate program: maximally reusable across all domains, maximally compressed (a handful of inference rules), maximally validated across longest timescale, and maximally cached (taught first, presupposed always). It’s the operating system that runs all other programs, the compiler that processes all other code, the foundation layer supporting all other applications.

The program metaphor also clarifies revision dynamics. Updating a rarely-used peripheral program costs little—just modify that specific routine. Updating a widely-used library function requires updating all code that calls it—higher cost but manageable. Updating the operating system requires recompiling everything—enormous cost. Updating the hardware definition language requires rebuilding the entire computational stack from scratch—effectively infinite cost. Logic occupies the hardware-definition layer: revising it requires rebuilding everything.

5.5 Coherence Builds Computational Closure

The final piece of the functional transformation mechanism is computational closure—how predicates create self-contained causal levels enabling efficient reasoning. This connects coherence to truth: predicates become true by achieving closure, and closure is earned through coherence under pragmatic pressure.

Computational closure occurs when coarse-grained variables at a higher level form a complete, self-contained dynamical system: future macro-states can be predicted from current macro-states without tracking micro-details. When a physician reasons about infectious disease, they use variables like “viral load,” “transmission route,” and “infection rate” without modeling underlying protein interactions, immune cell dynamics, or molecular processes. The disease-level variables achieve closure—they’re sufficient for prediction and intervention.

This closure is achieved through Markov blankets: statistical boundaries that compress environmental complexity into stable higher-level variables. When “...is an infectious disease” successfully compresses the relevant causal structure, it draws a blanket that shields medical reasoning from molecular complexity. Information flows across the blanket (viral load affects symptoms, treatment affects viral load), but the blanket compresses this complexity into tractable coarse-grained dynamics.

Failed predicates don’t achieve computational closure—they leak information. Miasma theory couldn’t explain disease transmission without constantly importing causal factors (water contamination, person-to-person contact) that violated its core principle (airborne miasmas). The leakage manifested as brittleness: accumulating anomalies, required patches, mounting explanatory debt. High brittleness signals closure failure.

Successful predicates achieve genuine closure: they carve reality at joints where coarse-graining preserves causal structure. Germ theory achieves closure because disease transmission actually operates through pathogen spread—the predicate

aligns with reality's causal grain. This alignment enables prediction without information leakage: germ theory's predictions consistently succeed, interventions work, and the framework requires minimal patching.

Logic achieves maximal closure: it provides the computational boundary for reasoning itself. Logical inference operates on propositional content without tracking neural implementation. You can derive conclusions from premises without modeling synaptic firing patterns, neurotransmitter dynamics, or neuronal connectivity. Logic compresses the physical process of reasoning into abstract rules operating on symbolic content.

This closure explains why logic is indispensable: reasoning requires some level of computational closure that abstracts from physical implementation. Any learning system must draw boundaries enabling efficient inference without tracking implementation details. Logic provides this closure at the most general level—it's the compression algorithm that works across all domains because it captures the abstract structure of inference itself.

Coherence builds closure through pragmatic filtering: predicates that maintain internal consistency while enabling successful prediction and intervention (coherence under pressure) achieve genuine computational closure. Those that maintain internal consistency but generate brittleness (coherence without viability) fail to achieve closure—their boundaries misalign with reality's causal structure.

Truth emerges when coherence builds closure: predicates become true by achieving stable positions where they maintain coherence under sustained pragmatic testing while enabling computational closure that supports further inquiry. Logic achieved truth by reaching the position of maximal closure—the boundary conditions for reasoning itself—through maximal coherence maintained across maximal scope and timescale. The architecture thus enables truth not as correspondence but as thermodynamically stable, pragmatically validated, computationally closed architectural achievement.

6. The Mechanics of Coherence-as-Truth

Having detailed how functional transformation enables beliefs to become truth, we now examine how coherence itself generates truth. Traditional coherentism faces the isolation objection: internal consistency doesn't guarantee contact with reality. We resolve this by showing how architectural coherence—coherence maintained under sustained pragmatic pressure within layered networks—builds truth through computational closure and convergent discovery.

6.1 Why Traditional Coherentism Fails

Traditional coherentist theories of justification and truth face a persistent challenge: the isolation objection (BonJour 1985). A belief system could achieve perfect internal coherence—all propositions mutually supporting, no contradictions, elegant explanatory structure—yet remain entirely detached from reality. Fictional narratives, delusional systems, and abandoned scientific theories all demonstrate internal coherence without truth.

Ptolemaic astronomy was internally coherent. Its practitioners could make predictions, explain observations, and reason consistently within the framework. The system's failure wasn't incoherence but empirical inadequacy—it misaligned with reality's actual structure, generating mounting brittleness as observations accumulated. Internal coherence proved insufficient for truth.

Similarly, phlogiston chemistry achieved significant coherence. Combustion, calcination, and respiration were unified under a single explanatory principle. The theory enabled successful reasoning and even some correct predictions. Its failure emerged through pragmatic inadequacy: phenomena kept leaking beyond the theory's explanatory boundaries, requiring endless ad hoc modifications.

Coherence without viability isn't truth.

The isolation objection reveals a fundamental gap in traditional coherentism: internal consistency is necessary but not sufficient for truth. Some external constraint is needed to distinguish viable coherent systems from merely consistent fantasies. But what external constraint, and how does it operate without reintroducing foundationalism?

Attempts to answer this within traditional coherentism have been unsatisfying. Appealing to observational beliefs as constraints (Olsson 2005) makes observations foundational, violating coherentism's holistic commitments.

Appealing to input-output correlations (Kvanvig 2012) leaves mysterious how these correlations validate entire belief systems. What's needed is an account of how coherence itself, properly understood, incorporates external constraints without abandoning holism.

6.2 Emergent Pragmatic Coherentism Solution

We resolve the isolation objection by redefining coherence: not as mere internal consistency but as demonstrated viability of entire knowledge systems measured through pragmatic success. Coherence in our sense requires not just mutual logical support among propositions but sustained capacity to minimize systemic brittleness under real-world application.

This shifts the explanandum. Traditional coherentism asks: what makes a belief justified given that it coheres with other beliefs? We ask: what makes an entire knowledge system viable given that it must function under pragmatic constraints? The unit of analysis isn't individual belief justification but system-level viability.

Pragmatic constraints provide the external filter traditional coherentism lacks—but without privileged foundational beliefs. Reality imposes costs on misaligned systems: failed predictions, ineffective interventions, accumulating anomalies, mounting complexity. These costs are objective (not subject to belief revision) and system-wide (affecting the entire network, not isolated beliefs). They function as external constraint without requiring incorrigible observational foundations.

The key innovation is brittleness as a diagnostic tool. Systemic brittleness measures accumulated costs signaling structural vulnerability. When a knowledge system generates persistent brittleness—requiring constant patching, producing failed interventions, accumulating anomalies—this indicates misalignment with reality's constraint structure. High brittleness is pragmatic refutation operating at the system level.

Crucially, brittleness accumulates holistically. An isolated false belief might generate little cost (it's quarantined from practical application). But a false belief embedded in a holistic web generates cascading costs as the system attempts to

maintain coherence around it. Phlogiston generated brittleness precisely because it was central to chemical explanation—every anomaly required system-wide adjustments.

Coherence in our sense thus means: internal consistency maintained while minimizing systemic brittleness through sustained pragmatic application. This isn't two separate conditions (coherence plus empirical adequacy) but a unified criterion: coherence-under-pressure. Systems achieving this unified coherence demonstrate genuine viability, not mere logical consistency.

6.3 How Architectural Coherence Differs

Architectural coherence differs from traditional coherence in four crucial dimensions, each reflecting the role of layered web structure in enabling truth.

Holistic Testing

Traditional coherence theories test propositions against each other: does this belief cohere with that belief? Architectural coherence tests entire systems against reality: does this network enable successful navigation of pragmatic constraints? The difference is profound. Individual propositions can achieve mutual consistency without the system being viable. But systems can't achieve sustained viability without genuine alignment with constraint structure.

The holistic testing operates through accumulated experience across diverse contexts. Germ theory wasn't validated by a single experiment but by success across epidemiology, surgery, public health, microbiology, and therapeutics. This distributed validation provides robust evidence that couldn't be achieved through isolated tests.

Layered Organization

Traditional coherence treats beliefs as relatively flat networks where all propositions are equally revisable in principle. Architectural coherence recognizes layered organization: predicates occupy different tiers with different revision costs, dependencies, and activation patterns. This creates differential brittleness sensitivity—core predicates must withstand broader challenges while peripheral predicates face immediate empirical pressure.

The layering enables localization of response. When anomalies emerge, the architecture responds at the appropriate level—peripheral adjustments for routine anomalies, domain restructuring for systematic crises, core reconsideration only for deep challenges. Traditional coherentism lacks this graduated response mechanism.

Dynamic Pressure

Traditional coherence is static: a system either coheres at a time or doesn't. Architectural coherence is dynamic: coherence must be maintained under sustained pragmatic pressure over time. This temporal dimension is crucial—anyone can construct momentarily coherent systems (conspiracy theories, pseudosciences, fictional narratives). Sustained coherence under evolving challenges distinguishes viable systems.

The dynamic aspect explains why some initially coherent theories fail. Phlogiston was coherent when first proposed and even for decades of application. Its failure emerged through accumulated brittleness as chemistry advanced. The system couldn't maintain coherence under sustained pressure from expanding empirical investigation.

Convergent Discovery

Traditional coherence operates within single systems: does this agent's belief set cohere? Architectural coherence incorporates convergent discovery: do multiple independent inquiry paths reach similar structures? When completely separate traditions (Western science, traditional knowledge systems, independent research lineages) converge on the same predicates, this provides powerful evidence for objective constraint-determination.

Germ theory emerged through convergent discovery—multiple researchers across different contexts independently developed similar frameworks. Logic achieved maximal convergence—Independent intellectual traditions across cultures and millennia codified essentially similar inference rules. This convergence indicates the predicates aren't culturally arbitrary but track objective features of reality and reasoning.

6.4 From Coherence to Program to Truth

The progression from coherence to truth proceeds through program formation. Predicates that maintain architectural coherence under sustained pragmatic pressure earn functional transformation, becoming programs (Standing Predicates) that enable further inquiry. These programs achieve truth not by corresponding to abstract facts but by occupying stable positions in viable knowledge architectures.

Stage 1: Initial Coherence

A predicate begins by achieving minimal coherence: it fits consistently within some knowledge system, enabling logical reasoning without contradiction. At this stage, coherence is merely Level 3 truth—contextual consistency without demonstrated viability. Many predicates remain here permanently (fictional categories, abandoned theories, speculative hypotheses).

Stage 2: Coherence Under Pressure

Through application, the predicate faces pragmatic testing. Does it enable successful prediction? Do interventions based on it work? Can it accommodate new observations without endless patching? Predicates that maintain coherence while demonstrating viability begin earning trust. This is the transition to Level 2 truth—justified by low-brittleness performance.

Stage 3: Program Formation

Predicates that succeed across sustained testing undergo functional transformation: from tested-data to tool-that-tests. They become programs—reusable, compressed, efficient tools that enable inquiry rather than requiring justification. Germ theory transformed from hypothesis to diagnostic framework; logical inference transformed from evaluated practice to evaluative standard.

This transformation has architectural significance: the predicate achieves computational closure, creating a new causal level that shields reasoning from underlying complexity. The closure is earned—it works because the predicate genuinely carves reality at viable joints, enabling prediction without information leakage.

Stage 4: Truth Achievement

At this stage, the predicate has achieved truth in our deflationary-yet-substantive sense. It occupies a position in viable knowledge architecture that enables

sustained successful application. To say it's "true" registers this functional achievement: the predicate has survived pragmatic filtering, earned entrenchment through demonstrated utility, achieved computational closure, and enabled cumulative inquiry.

For predicates reaching Level 1 (objective truth), an additional criterion is met: convergent discovery across multiple independent inquiry paths. This indicates the predicate occupies an objective attractor point—a constraint-determined structure that any viable system must discover.

The Role of Coherence

Throughout this progression, coherence plays a constitutive role. Not mere internal consistency but coherence-under-pressure: the capacity to maintain mutual support among propositions while facing pragmatic challenges. Predicates achieving this robust coherence earn program status, and programs achieving maximal coherence across maximal scope earn truth status.

Truth is thus architectural achievement built from coherence: predicates become true by maintaining coherence under sustained pragmatic pressure within layered networks, achieving computational closure that enables further inquiry, and (for objective truth) being convergently discovered across independent traditions.

6.5 Logic as Maximally Coherent Program

Logic represents the endpoint of this progression: the maximally coherent program occupying the deepest architectural layer. Understanding logic's coherence illuminates both its necessity and its naturalistically explicable emergence.

Internal Coherence

Logic achieves maximal internal coherence: its rules mutually support each other, form a minimal consistent set, and enable systematic reasoning without contradiction. Modus ponens, non-contradiction, excluded middle, and other logical principles form a tightly integrated system where each rule reinforces others. This internal coherence explains why logic feels self-evident—it's an optimally compressed, maximally consistent set of inference rules.

Coherence Under Maximal Pressure

But logic's distinguishing feature is maintaining coherence under maximal pragmatic pressure. Logic has been tested across:

- Maximal temporal scope (billions of years of evolutionary selection plus millennia of explicit testing)
- Maximal domain scope (mathematics, science, philosophy, law, everyday reasoning)
- Maximal challenge variety (empirical anomalies, paradoxes, alternative proposals, conceptual puzzles)

Every test has validated logic. Every attempted alternative has either reduced to logic for general purposes or proved unworkable. This is unparalleled validation—no other predicate system approaches logic's track record.

Maximal Computational Closure

Logic achieves closure at the deepest level: inference itself. All reasoning employs logical structure; there is no meta-level reasoning that doesn't presuppose logic. This creates pragmatic circularity—you cannot evaluate logic without using logic—but the circularity isn't vicious. It indicates logic occupies the operating-system layer rather than application level.

This maximal closure explains logic's indispensability. Any learning system must draw computational boundaries enabling efficient inference. Logic provides these boundaries at the most general level: abstract rules capturing inference structure applicable across all domains. The closure is earned—logic works precisely because it compresses reality's logical structure into efficient rules.

Maximal Convergence

Logic demonstrates maximal convergent discovery. Independent traditions across cultures, time periods, and intellectual frameworks developed essentially similar logical systems:

- Ancient Greek syllogistic logic (Aristotle)
- Classical Indian logic (Nyaya school)
- Traditional Chinese logic (Mohist school)
- Islamic logical traditions
- Modern formal systems (Frege, Russell, contemporary logic)
- Artificial intelligence implementations

This extraordinary convergence indicates logic occupies an objective attractor point. Not culturally arbitrary, not historically contingent, but constraint-determined: any viable knowledge system must implement logical structure to succeed. The convergence validates logic's claim to Level 1 (objective) truth.

Why Logic's Coherence Generates Necessity

Logic's felt necessity emerges from its coherence profile: maximal internal consistency, perfect track record under maximal pressure, deepest computational closure, and widest convergent discovery. This combination creates functional unrevisability for bounded agents.

An alternative to logic would need to:

1. Match or exceed logic's internal coherence (challenging given logic's optimal compression)
2. Demonstrate superior performance across all domains where logic succeeds (no candidate has)
3. Provide equivalent computational closure for inference (requiring reinventing reasoning itself)
4. Explain away the convergent discovery of logic across independent traditions (conspiracy of massive scale)

No alternative meets these requirements. This isn't conservatism but rational assessment: logic occupies a stable attractor in the space of viable inference systems, and moving away requires prohibitive costs with no demonstrated benefits.

The necessity is therefore pragmatic, not metaphysical. Logic feels necessary because for us—with our history, dependencies, and architectural commitments—it is functionally necessary. But the functional necessity emerged through naturalistic processes: evolutionary selection, cultural validation, progressive entrenchment, and convergent discovery. The mystery dissolves while the phenomenon remains.

Truth, from this perspective, is maximized coherence: predicates become true by achieving stable positions where they maintain maximal internal consistency while demonstrating maximal viability under maximal pressure across maximal scope, achieving maximal computational closure, and (ideally) being convergently discovered. Logic exemplifies this maximization—it's what truth looks like at the extreme limit of coherence-under-pressure.

7. Worked Example: Germ Theory

To see the framework in action, we trace germ theory's displacement of miasma theory in 19th-century medicine. This historical episode demonstrates functional transformation, predicate migration, activation dynamics, and the role of logic as constant background.

7.1 Pre-Germ Theory Activation Patterns

Mid-19th century medicine operated with miasma theory as its Standing Predicate for disease causation. "...is caused by miasmas" (noxious emanations from decaying matter) structured medical reasoning and public health policy. The predicate activated routinely:

- **Diagnosis:** Diseases in areas with foul odors were attributed to miasmic influence
- **Treatment:** Improving air quality, avoiding swamps, burning aromatic substances
- **Public health:** Draining marshes, improving sanitation to reduce odors
- **Theory:** Disease patterns explained by atmospheric conditions and "bad air"

Miasma theory occupied Tier 4 (domain-specific Standing Predicate) in the medical network. It presupposed Tier 3 predicates (causation, disease as natural phenomenon) and Tier 2 (conservation laws, material processes). Tier 1 logic remained constantly active: physicians reasoned about disease causally, drew inferences from symptoms, eliminated inconsistent hypotheses.

The theory achieved significant coherence. It explained disease clustering in certain areas (swamps, urban slums), accounted for seasonal variations (more disease in summer when decay is active), and integrated with broader medical theory. Most importantly, it enabled action: public health measures based on miasma theory (improving sanitation, draining swamps) often worked—though for reasons the theory misunderstood.

7.2 Recalcitrant Experience Accumulates

However, brittleness accumulated at the edges. Three types of anomalies created mounting pressure:

Empirical anomalies: Ignaz Semmelweis (1847) demonstrated that handwashing with chlorinated lime dramatically reduced puerperal fever in maternity wards—from 18% mortality to under 2%. This made little sense in miasma theory: why would hand hygiene affect airborne miasmas? The theory could accommodate it through ad hoc modifications (perhaps contaminated hands released miasmas), but the explanation felt forced.

Transmission patterns: John Snow's cholera investigations (1854) showed disease spreading through water supply, not air. The Broad Street pump outbreak was contained by removing the pump handle, stopping disease transmission despite continued "miasmic" conditions. Miasma theory struggled: why would water-borne transmission occur for a supposedly airborne disease?

Microscopic observations: Developments in microscopy revealed microorganisms consistently associated with specific diseases. Louis Pasteur (1860s) demonstrated that fermentation and spoilage resulted from microbial action, not spontaneous generation. Robert Koch (1870s-80s) isolated specific

bacteria causing anthrax, tuberculosis, and cholera. The consistent microorganism-disease associations demanded explanation.

Each anomaly individually could be accommodated through peripheral adjustments. But collectively, they created systematic brittleness: the theory required increasingly elaborate patches, lost predictive power, and failed to unify the mounting evidence. The brittleness signaled misalignment—the predicate wasn't carving reality at viable joints.

7.3 Network Revision and Predicate Migration

The accumulating brittleness triggered network revision. Rather than abandoning disease theory entirely, the architecture localized revision to Tier 4: domain-specific medical predicates. Germ theory emerged as an alternative framework:

New predicate introduced: "...is caused by specific living microorganisms" (germs, bacteria, viruses) entered as a Stage 1 hypothesis competing with miasma theory.

Local validation: The predicate rapidly demonstrated utility: - Koch's postulates provided systematic methodology for linking specific organisms to specific diseases - Antiseptic surgical techniques (Lister, 1860s) dramatically reduced post-operative infections - Pasteurization prevented spoilage and disease transmission through milk - Public health measures targeting pathogen transmission (water treatment, quarantine) proved more effective than anti-miasma approaches

Functional transformation: Within decades, germ theory underwent transformation from tested-hypothesis to tool-that-tests. By the early 20th century, when encountering a novel disease, physicians didn't ask "Is this caused by germs or miasmas?" but "Which pathogen causes this? What's the transmission route?" The predicate had become diagnostic infrastructure.

Domain restructuring: Germ theory's success required restructuring medical sub-domains: - Epidemiology: Focus shifted from environmental conditions to transmission chains - Surgery: Sterile technique became foundational - Public health: Interventions targeted pathogen vectors (water treatment, vaccination, quarantine) - Therapeutics: Development of antimicrobial treatments (antiseptics, later antibiotics)

Crucially, the revision remained localized. Tier 3 predicates (causation, disease as natural phenomenon) persisted unchanged. Tier 2 (material processes, conservation laws) continued operating. Tier 1 logic was never questioned—it provided the inferential machinery for evaluating competing theories.

7.4 New Activation Patterns Stabilize

Germ theory achieved Standing Predicate status (Stage 3) and eventually convergent core entry within medicine (Stage 4). New activation patterns emerged:

Routine diagnosis: "...is an infectious disease" now automatically activates for appropriate cases, unpacking diagnostic protocols: identify the pathogen, determine transmission route, implement infection control, consider antimicrobial treatment.

Functional unrevisability: While technically revisable, abandoning germ theory would require rebuilding modern medicine. Microbiology, immunology, epidemiology, infectious disease medicine, vaccine development, and antimicrobial therapeutics all presuppose germ theory. The revision cost is prohibitive.

Computational closure: Germ theory achieves genuine closure. You can reason about disease transmission, predict epidemic dynamics, and design interventions using pathogen-level variables (virulence, transmission rate, incubation period) without modeling molecular biology. The theory carves reality at a viable joint.

Miasma theory migrated to the Negative Canon—the repository of abandoned approaches. It's taught historically as a cautionary tale, demonstrating how internally coherent theories can fail through pragmatic inadequacy. The failure wasn't irrationality but brittleness accumulation forcing revision.

7.5 How Logic Underlies the Germ Theory Case

Throughout this episode, logic remained constantly active as the operating system for inquiry. Every step presupposed logical inference:

Anomaly detection: “If miasma theory predicts X, but we observe not-X, then miasma theory faces challenge.” (Modus tollens)

Theory comparison: “Either disease is caused by miasmas or by germs; extensive evidence contradicts miasma causation; therefore germ causation is supported.” (Disjunctive syllogism)

Causal inference: “Every case of cholera traces to contaminated water; contaminated water contains specific microorganisms; therefore these microorganisms likely cause cholera.” (Inductive generalization)

Hypothesis testing: “If germ theory is correct, then sterilization should prevent disease; sterilization does prevent disease; this supports germ theory.” (Hypothetico-deductive reasoning)

Logic wasn't questioned during this scientific revolution—it was the tool used to adjudicate between theories. Physicians employed modus ponens to derive predictions, non-contradiction to eliminate inconsistent hypotheses, and excluded middle to frame alternatives. The revolution occurred within logic, not to logic.

This pattern holds for all scientific revisions: domain-specific predicates (Tier 4) are revised when brittleness accumulates; domain-general frameworks (Tier 3) are revised in deep crises; mathematical and physical principles (Tier 2) are revised in revolutionary episodes; but logic (Tier 1) remains operative throughout, providing the inferential machinery for evaluation.

The germ theory case thus demonstrates the full framework in microcosm: activation dynamics (which predicates are questioned), functional transformation (from hypothesis to tool), coherence-under-pressure (maintaining viability), computational closure (achieving stable causal levels), and logic's constant background role (the operating system for inquiry). Understanding this mechanism illuminates how truth emerges through architectural position rather than metaphysical correspondence.

8. Objections and Responses

This framework faces several important objections. Addressing them clarifies the position and reveals its implications.

8.1 “Isn’t this just relativism?”

Objection: If truth is functional position within knowledge architectures rather than correspondence to reality, doesn’t this collapse into relativism? Different architectures might validate different “truths,” making truth relative to frameworks.

Response: Three factors prevent relativist collapse. First, pragmatic constraints are objective and non-negotiable. Reality imposes costs on misaligned systems regardless of what participants believe. A system validating “the Earth is flat” accumulates navigational brittleness regardless of internal coherence. The costs are external constraints, not subjective preferences.

Second, convergent discovery indicates objective attractors. Independent inquiry traditions facing the same constraints converge on similar structures (logic, thermodynamics, germ theory). This convergence can’t be explained by social coordination—many traditions developed in isolation. It indicates constraint-determined optimal configurations that any viable system must discover.

Third, brittleness provides falsification at the system level. High-brittleness systems fail in practice: they generate mounting costs, lose explanatory power, and eventually collapse or transform. This pragmatic failure operates independently of participants’ beliefs about truth. Failed systems don’t persist because participants believe in them; they’re abandoned because they don’t work.

Truth is therefore objective in the relevant sense: there are mind-independent facts about which configurations minimize brittleness, and these facts constrain viable architectures. But truth isn’t correspondence to Platonic forms—it’s alignment with constraint structure revealed through pragmatic filtering. The objectivity is thermodynamic, not metaphysical.

8.2 “Why can’t we revise logic?”

Objection: The framework claims logic is revisable in principle but functionally unrevisable in practice. But history shows we have revised logic: non-Euclidean geometries replaced Euclidean axioms, quantum logic was developed for quantum mechanics, paraconsistent logics handle contradictions. Doesn’t this demonstrate logic’s revisability?

Response: These cases illustrate the distinction between revising specialized logical systems and revising core logical principles. Non-Euclidean geometry revised geometric axioms, not logical inference rules—both Euclidean and non-Euclidean geometry employ modus ponens, non-contradiction, and standard logical inference. The revision occurred within logic, not to logic.

Quantum logic and paraconsistent logics are specialized systems for particular domains. They don’t replace classical logic for general reasoning—they supplement it for specific contexts. Crucially, these alternative logics are evaluated using classical logical reasoning: we use modus ponens to derive their consequences, check their consistency (or controlled inconsistency), and assess their utility. Classical logic remains the meta-language for evaluating alternatives.

More precisely, within our architectural framework, alternative logics function as domain-specific Standing Predicates (Tier 4) while classical logic remains at Tier 1. Paraconsistent logic achieves computational closure for reasoning with inconsistent databases without threatening classical logic's status as the general-purpose inferential framework. Intuitionistic logic tracks computational content in constructive mathematics. Quantum logic captures non-classical features of quantum phenomena. These systems work within the broader architecture governed by classical logic, not as replacements for it. They are specialized tools for contexts where classical logic generates unnecessary brittleness or fails to track relevant structure, but they presuppose classical logic for their own evaluation and application.

We cannot rule out the possibility that future inquiry might migrate toward a different core if alternative logics consistently enabled superior prediction and intervention across widening domains. Our framework predicts such migration would occur if the pragmatic pressure were sufficient. The functional unrevisability of classical logic is historically achieved, not metaphysically guaranteed. However, given the current state of inquiry, no alternative has demonstrated the universal scope and sustained success necessary to challenge classical logic's core position. The architectural account thus accommodates the possibility of logical revision in principle while explaining why such revision remains implausible in practice.

Could we revise core logical principles like modus ponens or non-contradiction? In principle, yes—we can imagine alternatives. In practice, the costs are prohibitive: every knowledge structure presupposes these principles, questioning them requires using them (pragmatic circularity), and no viable general-purpose alternative has emerged despite extensive exploration. The functional unrevisability reflects accumulated dependencies and proven success, not metaphysical necessity.

The key insight: logic's core status was earned through maximal pragmatic success over maximal scope and timescale. Different evolutionary histories might have produced different cognitive architectures, but given our actual history, logic is locked in place by astronomical revision costs combined with zero brittleness pressure for change.

8.3 “Where does mathematics fit?”

Objection: Mathematics seems intermediate between logic and empirical predicates. Is it Tier 1 (like logic) or Tier 2? How did mathematical predicates achieve their status?

Response: Mathematics occupies Tier 2—near-core but more revisable than logic. This placement reflects several factors:

First, mathematics presupposes logic but not vice versa. Logical inference operates without mathematical concepts, but mathematical proof employs logical reasoning. The dependency is asymmetric, placing logic deeper.

Second, mathematics has been revised historically. Non-Euclidean geometries replaced Euclidean axioms as foundational; set-theoretic paradoxes forced revisions to set theory; debates about infinity and constructivism show mathematical principles remain contested. These revisions demonstrate mathematics doesn't enjoy logic's functional unrevisability.

Third, mathematics emerged through pragmatic validation similar to other Standing Predicates. Early arithmetic developed for practical purposes (counting,

trading, construction). As these patterns proved reliable across expanding contexts, they became entrenched. Euclidean geometry dominated for two millennia because it worked at human scales. Only when inquiry reached cosmological scales did evidence accumulate for revision.

Fourth, mathematics achieves extraordinary but not maximal scope.

Mathematical reasoning applies across theoretical domains but isn't presupposed by all inquiry the way logic is. You can investigate history, evaluate ethical arguments, or engage in legal reasoning with minimal mathematics, but you cannot do any of these without logical inference.

Mathematics thus exemplifies the same emergence mechanism as other Standing Predicates, just operating at near-core rather than core level. It achieved Tier 2 status through extensive pragmatic validation, but remains more revisable than logic due to narrower scope and shallower dependencies.

8.4 “Isn’t logic different in kind from other Standing Predicates?”

Objection: The framework claims logic differs from germ theory only in degree (timescale, scope, dependencies), not kind. But logic seems qualitatively different—it's constitutive of reasoning itself, presupposed by all inquiry, and seemingly unrevisable. Doesn't this make it categorically distinct?

Response: The appearance of categorical difference emerges from degree taken to the extreme. Consider an analogy: speed seems categorically different at light speed (causality constraints, time dilation) versus everyday speeds. But the underlying physics is continuous—relativistic effects scale with velocity, becoming dramatic only at extreme values. Similarly, entrenchment, dependencies, and validation scope are continuous variables that generate apparent categorical differences at extreme values.

Logic has:
- Longest timescale (billions of years evolutionary + millennia cultural)
- Widest scope (universal across all domains)
- Deepest dependencies (all inquiry presupposes it)
- Perfect track record (no viable alternatives emerged)

These extreme values create qualitative effects: pragmatic circularity (can't question logic without using it), functional unrevisability (infinite revision cost), and felt necessity (cannot imagine alternative). But these are consequences of degree, not intrinsic categorical differences.

The emergence mechanism is identical: proto-logical patterns succeeded pragmatically → explicit formulation → validation across contexts → functional transformation → entrenchment → core migration. Germ theory follows the same path, just across shorter timescales and narrower scope. Both are Standing Predicates that earned their architectural positions through demonstrated viability.

The critical insight: logic's specialness is its architectural position after maximal validation, not its metaphysical nature. If there were predicates with even longer validation and wider scope, they would seem “more foundational” than logic.

Logic represents the empirical limit of this progression, not a categorically distinct kind.

8.5 “How do new predicates enter the system?”

Objection: If the architecture is structured by entrenchment and dependencies, how do genuinely novel predicates get introduced? Doesn’t entrenchment create conservatism that resists innovation?

Response: New predicates enter continuously at the periphery (Tier 4-5) where revision costs are low. Scientists propose novel categorizations, investigators develop new frameworks, researchers test alternative explanations. Most proposed predicates fail and are abandoned, but successful ones begin migrating inward through the five-stage progression.

The architecture enables innovation through localized revision. When chemists proposed oxygen theory to replace phlogiston, they didn’t need to revise all of chemistry simultaneously—they revised domain-specific causal explanations while preserving general chemical principles, thermodynamics, and logic. The layered structure allows innovation at peripheral/intermediate layers while maintaining core stability.

Entrenchment creates appropriate conservatism: well-established principles shouldn’t be revised casually, as they’ve proven their worth through sustained success. But entrenchment isn’t dogmatism—brittleness accumulation provides pressure for revision when predicates fail pragmatically. The balance between stability (entrenchment) and flexibility (revision under brittleness pressure) enables both cumulative progress and revolutionary change.

Innovation is thus continuous but filtered: new predicates constantly proposed → pragmatically tested → successful ones migrate inward → failed ones abandoned → architecture gradually evolves while maintaining structural integrity.

8.6 “What about perceptual beliefs?”

Objection: The framework focuses on theoretical predicates, but what about observational reports and perceptual beliefs? Where do “I see red now” or “The instrument reads 5.3” fit in the architecture?

Response: Perceptual beliefs occupy the periphery—they’re the most revisable and episodically activated predicates. When an observation conflicts with theory, we readily question whether we perceived correctly, whether instruments malfunctioned, whether conditions were standard. Perceptual reports have minimal entrenchment and few dependencies, making them maximally revisable.

However, even perceptual predicates presuppose Standing Predicates. “I see red” presupposes color concepts, perceptual categories, and phenomenal experience concepts. “This instrument reads 5.3” presupposes measurement theory, causal interaction, and instrumentation principles. The periphery connects to deeper layers through presupposition chains.

The architecture thus accommodates both observation’s epistemic importance (it’s where theory meets world) and its high revisability (individual observations are easily questioned). Observational predicates provide input for brittleness assessment—they’re how pragmatic pushback enters the system—but they don’t enjoy privileged epistemic status. They’re as subject to revision as any predicate, just with lower costs for doing so.

This resolves traditional epistemological puzzles about the “given” in experience. There is no incorrigible observational foundation—even perceptual reports are theory-laden and revisable. But there is pragmatic constraint—observations that

persistently conflict with theory generate brittleness that forces revision somewhere in the network. The constraint is real without requiring foundational certainty.

These responses clarify the framework's position: it avoids relativism through objective pragmatic constraints, explains logic's special status through degree rather than kind, accommodates innovation while maintaining stability, and handles perception without requiring foundational certainty. The next section explores the framework's implications across multiple philosophical domains.

9. Implications and Future Directions

The framework generates significant implications across multiple philosophical domains, suggesting directions for future development.

9.1 For Philosophy of Science

The framework reconceptualizes scientific revolutions as large-scale predicate restructuring events rather than paradigm replacements in Kuhn's sense. When phlogiston was replaced by oxygen theory, when caloric theory gave way to kinetic theory, when Newtonian mechanics was supplanted by relativity—these weren't wholesale worldview changes but localized revisions at specific architectural levels.

This explains both continuity and discontinuity in scientific progress. Continuity: deeper layers (causation, material ontology, logic) persist through revolutions, enabling rational theory comparison. Discontinuity: domain-specific predicates undergo transformation, creating incommensurability at that level while preserving commensurability at deeper levels.

The framework also provides a naturalistic account of theory choice. Scientists aren't choosing between incommensurable paradigms based on subjective values. They're responding to brittleness accumulation: theories generating mounting costs, requiring endless patches, losing explanatory power are abandoned for alternatives demonstrating lower brittleness. The choice is constrained by objective pragmatic pressures.

Future work should apply this framework to specific historical cases: the chemical revolution, the development of quantum mechanics, the molecular biology revolution. Can brittleness metrics capture the actual dynamics of theory change? Do activation patterns match historical evidence about which commitments were questioned when?

9.2 For Epistemology

The framework dissolves traditional epistemological dichotomies. *A priori* versus *a posteriori*: all knowledge sits on the same continuum of pragmatic validation, distinguished by degree of entrenchment and scope rather than kind of justification. Analytic versus synthetic: the distinction tracks revision cost rather than metaphysical categories—"all bachelors are unmarried" is highly entrenched

definitionally, but this reflects linguistic convention crystallized through use, not timeless conceptual truth.

The framework also naturalizes epistemic norms without relativism. Epistemic rationality is minimizing systemic brittleness: believing propositions certified by low-brittleness networks, revising when brittleness accumulates, maintaining coherence under pragmatic pressure. These norms emerge from the functional requirements of viable knowledge systems, not from asubjectivist foundations or mere convention.

For traditional epistemology's focus on justified belief, the framework shifts to justified knowledge systems. Individual beliefs are justified derivatively through their position in viable architectures. This resolves Gettier cases naturally: they involve beliefs that happen to be true but lack appropriate architectural position—they're accidentally true rather than structurally validated.

Future epistemological work should develop brittleness diagnostics applicable to contemporary knowledge domains: how do we assess the viability of climate models, economic theories, or AI safety frameworks? Can we identify early warning signs of systemic fragility before catastrophic failures?

9.3 For Philosophy of Logic

The framework's most radical implications concern logic itself. Traditional philosophy treats logic as either empirical (Mill, Quine) or *a priori* necessary (Kant, Frege). We chart a middle path: logic is empirically justified through pragmatic success but achieves functional necessity through maximal entrenchment.

This dissolves puzzles about logical revisability. We can explain why logic seems both necessarily true (functionally unrevisable given our dependencies) and theoretically revisable (we can imagine alternatives). The felt necessity reflects position, not intrinsic nature. Different cognitive architectures might implement different logical structures, but given our history, classical logic is locked in.

The framework also naturalizes the normativity of logic without appealing to abstract logical facts. Logical principles are normative because violating them generates systemic costs—contradiction-accepting reasoning proves unworkable, invalid inference leads to false conclusions. The normativity emerges from pragmatic consequences, not from grasping Platonic truths.

This vindicates Quine's critique of analyticity and necessity while preserving the phenomena he aimed to preserve: logic's centrality, mathematics' robustness, and the existence of propositions we won't actually revise. But we explain these without appeal to meaning, analyticity, or necessity—only to architectural position earned through pragmatic filtering.

Future work in philosophy of logic should investigate alternative logics' status: are paraconsistent and quantum logics genuine alternatives or specialized subsystems? Can we predict which logical principles are truly unrevisable versus which might yield to sufficient pressure? How do we evaluate proposals for logical revision without presupposing the logic being evaluated?

9.4 For Cognitive Science

The framework predicts specific neural implementation patterns. If predicates organize hierarchically with differential activation, we should find corresponding

neural architecture: deeper layers (logic, basic categories) implemented in phylogenetically older, more widely distributed neural structures; peripheral predicates (domain-specific knowledge, recent learning) in more recent, localized structures.

The cost landscape should manifest neurally: high-entrenchment predicates should show greater synaptic strength, wider neural distribution, and greater resistance to degradation. Brain damage affecting core predicates (logic, basic reasoning) should be catastrophic for all cognition; damage to peripheral predicates (specific memories, specialized knowledge) should be more localized in effect.

The framework also connects to predictive processing models (Clark 2016; Friston 2010). Standing Predicates function as high-level priors that shape lower-level prediction. Brittleness corresponds to prediction error accumulation: systems generate mounting surprise when their priors misalign with sensory evidence. Functional transformation occurs when predicates migrate from being-predicted (tested against evidence) to predicting (generating expectations for lower levels).

Future cognitive science research should test these predictions: Do neural implementations match the predicted architectural organization? Does brain damage selectively affect predicates according to their tier? Can we observe functional transformation neurally as new concepts are learned and entrenched?

9.5 For Evolutionary Epistemology

The framework extends Campbell's (1974) evolutionary epistemology by explicating specific mechanisms. Knowledge evolves through variation (proposing new predicates), selection (pragmatic filtering via brittleness), and retention (entrenchment of successful predicates). But unlike biological evolution, epistemic evolution is Lamarckian: acquired characteristics (validated predicates) are directly transmitted across generations through cultural learning.

This explains rapid cultural evolution compared to biological evolution. Biological evolution requires generational selection on random mutations. Epistemic evolution employs directed learning: we try solutions informed by previous experience, immediately propagate successful innovations, and accumulate improvements across generations through teaching.

The framework also predicts convergent evolution of knowledge systems. Independent lineages facing similar constraints should converge on similar predicates—not through coordination but through parallel discovery of optimal configurations. We observe this: independent invention of agriculture, mathematics, logical systems, and scientific methods across isolated cultures. The convergence indicates objective constraint structure guiding evolution.

Extending the framework to artificial intelligence suggests predictions: AI systems should independently discover logical structure because it's thermodynamically optimal for inference; successful AI will implement hierarchical predicate organization with core-periphery structure; AI failure modes should track high brittleness (inability to maintain coherence under diverse inputs).

Future work should trace knowledge system evolution across cultures: Do independent traditions converge on similar Standing Predicates when addressing similar problems? What mechanisms enable convergent discovery without communication? Can we identify universal cognitive attractors that all viable knowledge systems must reach?

These implications demonstrate the framework's breadth: it reconceptualizes scientific change, naturalizes epistemic norms, explains logical necessity pragmatically, predicts neural implementation patterns, and extends evolutionary epistemology. The common thread is understanding truth as architectural achievement earned through pragmatic filtering within hierarchically organized knowledge systems. The final section synthesizes these insights.

10. Conclusion

This paper has developed an account of how beliefs become truth through architectural transformation within hierarchically organized knowledge systems. The central insight is that truth is not correspondence to abstract facts but functional achievement earned through sustained pragmatic validation.

The Architectural Mechanism

The Quinean web of belief is more than metaphor—it's the essential mechanism enabling truth. The web's layered, hierarchical structure creates differential activation patterns, revision costs, and entrenchment dynamics that together enable functional transformation. Predicates migrate from tentative hypotheses at the periphery to core infrastructure through a five-stage progression: initial proposal, local validation, functional transformation (from tested-data to tool-that-tests), entrenchment, and migration to core.

This progression operates uniformly from domain-specific scientific predicates to foundational logical principles. The same mechanism that elevated germ theory from hypothesis to medical cornerstone elevated logic from proto-patterns in organisms to the operating system for all inquiry. The difference is one of degree —timescale, scope, dependencies—not fundamental kind.

The Emergence of Logic

The paper's most radical claim is that even logic itself—paradigm of necessary, *a priori* truth—achieved its foundational status through this pragmatic mechanism. Logic didn't spring fully formed from rational intuition or metaphysical necessity. It emerged through billions of years of evolutionary selection on organisms implementing proto-logical inference patterns, was explicitly codified by ancient philosophers recognizing successful reasoning structures, underwent sustained pragmatic validation across all domains of inquiry, became progressively entrenched as generations built on logical infrastructure, and eventually achieved core status through accumulated dependencies making revision functionally impossible for bounded agents.

Logic occupies the absolute core not because of what it is (abstract necessary truths) but because of where it is (the foundational layer after maximal validation across maximal scope over maximal timescale). The position was earned through the longest track record of pragmatic success humanity has ever accumulated. Logic feels necessary because for us—with our history, dependencies, and architectural commitments—it is functionally necessary. But this functional necessity emerged through thoroughly naturalistic processes.

This dissolves the traditional mystery while preserving the phenomenon. We can explain why logic seems unrevisable (astronomical revision costs with zero

brittleness pressure for change) without appealing to metaphysical privilege. We can explain its universality (convergent discovery across independent traditions facing the same constraints) without requiring Platonic forms. We can explain its normativity (violating logic generates systemic costs) without invoking abstract rational intuitions.

Coherence Builds Truth

Traditional coherentism fails because internal consistency doesn't guarantee truth—fictional systems can achieve perfect coherence while remaining detached from reality. We resolve this through architectural coherence: coherence maintained under sustained pragmatic pressure within layered networks. This isn't two separate conditions (coherence plus empirical adequacy) but a unified criterion: coherence-under-pressure.

Predicates achieving architectural coherence earn functional transformation. They become Standing Predicates—reusable programs that compress successful practices into efficient tools enabling further inquiry. These programs achieve computational closure, drawing Markov blankets that shield reasoning from lower-level complexity while preserving prediction accuracy. Failed predicates leak information—they require constant patches, generate mounting anomalies, and accumulate brittleness signaling misalignment with reality's constraint structure.

Truth emerges when predicates maintain architectural coherence through sustained testing, achieve computational closure enabling further inquiry, accumulate dependencies that increase revision costs, and (for objective truth) are convergently discovered across independent inquiry traditions. This is truth as thermodynamically stable, pragmatically validated, computationally closed architectural achievement.

Deflationary Yet Substantive

The framework adopts a deflationary approach to truth's metaphysics while offering a substantive account of truth's achievement. Deflationarily, "is true" doesn't denote a deep metaphysical property or correspondence relation. It primarily serves logical and expressive functions—enabling generalization over propositions, endorsing claims, reasoning about beliefs.

But deflation doesn't make truth vacuous or merely conventional. Truth tracks substantive functional role: a proposition's position within viable knowledge architectures. To attribute truth is to register that the proposition occupies a certain architectural position—it's certified by low-brittleness networks, has survived pragmatic filtering, enables successful prediction and intervention, and (ideally) aligns with constraint-determined optimal configurations.

This generates three levels of truth-attribution corresponding to different degrees of validation: contextual coherence (Level 3), justified truth certified by low-brittleness networks (Level 2), and objective truth aligned with the Apex Network that independent inquiries converge upon (Level 1). Logic occupies Level 1—it represents an objective attractor point that any viable learning system must discover.

Radical Naturalism Without Relativism

The framework achieves radical naturalism: all knowledge, including logic and mathematics, sits on the same continuum of pragmatic validation. There is no metaphysical rupture between empirical and logical truth, no categorical distinction between *a priori* and *a posteriori* knowledge, no fundamental difference between analytic and synthetic propositions. All truth is architectural

achievement earned through functional transformation within hierarchically organized knowledge systems.

Yet this radical naturalism avoids relativist collapse through three factors. First, pragmatic constraints are objective—reality imposes costs on misaligned systems regardless of what participants believe. Second, convergent discovery indicates objective attractors—*independent traditions facing identical constraints converge on similar structures*. Third, brittleness provides system-level falsification—high-brittleness systems fail in practice, demonstrating pragmatic inadequacy independently of participants’ beliefs about truth.

Truth is therefore objective in the relevant sense: there are mind-independent facts about which configurations minimize brittleness, and these facts constrain viable knowledge architectures. But the objectivity is thermodynamic rather than metaphysical—it concerns optimal solutions to pragmatic problems rather than correspondence to Platonic realms.

The Power of Architecture

Understanding truth as architectural achievement illuminates numerous philosophical puzzles. It explains why logic seems both necessary and potentially revisable: the necessity is pragmatic (functionally unrevisable given our dependencies), the potential revisability is theoretical (we can imagine alternatives). It explains theory choice in science: scientists respond to brittleness accumulation by adopting lower-brittleness alternatives. It explains convergent discovery: independent traditions facing identical constraints reach similar configurations because reality’s constraint structure determines optimal solutions.

The framework also predicts patterns we observe: scientific revisions typically occur at domain-specific levels while preserving deeper frameworks; logical inference remains constant across scientific revolutions; mathematical principles are more revisable than logic but less than empirical theories; perceptual reports are maximally revisable despite being epistemically foundational.

Most importantly, the architectural perspective enables cumulative progress. Each generation inherits Standing Predicates as cached infrastructure, enabling them to build further rather than starting from scratch. Logic provides the operating system, mathematics the standard libraries, domain-general frameworks the application interfaces, and domain-specific Standing Predicates the specialized tools. This accumulated architecture explains humanity’s spectacular epistemic success despite individual cognitive limitations.

Future Directions

This framework opens numerous research directions. Empirically, we should test whether neural implementations match the predicted hierarchical organization, whether brain damage selectively affects predicates according to their tier, and whether AI systems independently discover logical structure as the framework predicts.

Historically, we should trace predicate emergence and migration across actual scientific episodes: Does brittleness accumulation precede theory revision? Do activation patterns match which commitments were questioned when? Can we identify the five-stage progression in historical cases?

Philosophically, we should develop brittleness diagnostics for contemporary knowledge domains, investigate the status of alternative logics, explore whether mathematical predicates follow the same emergence patterns, and examine how

the framework applies beyond theoretical knowledge to practical reasoning, ethical norms, and aesthetic judgments.

The Journey from Beliefs to Truth

Beliefs become truth by achieving certain architectural positions through sustained pragmatic success. The journey proceeds through articulation (beliefs crystallize into propositions), coherence testing (propositions achieve internal consistency), pragmatic validation (propositions face real-world pressure), functional transformation (successful predicates become tools), entrenchment (tools become infrastructure), and convergence (infrastructure aligns with constraint-determined optimal configurations).

Logic exemplifies this journey at maximum scale: from proto-logical patterns in organisms to behavioral rules in early humans to explicitly codified systems in ancient philosophy to universally presupposed infrastructure in modern inquiry. The journey took billions of years, encompassed all domains, created universal dependencies, and achieved perfect validation—making logic functionally unrevisable for bounded agents while remaining naturalistically explicable.

Understanding this mechanism—how web architecture enables functional transformation of beliefs into truth through coherence maintained under pragmatic pressure—illuminates both the structure of knowledge and the nature of truth itself. Truth is not correspondence to a Platonic realm but architectural achievement: predicates earning their positions through demonstrated viability, accumulating dependencies through successful application, and achieving closure that enables further inquiry.

This is truth as we actually encounter it: hard-won, pragmatically validated, hierarchically organized, enabling cumulative progress, and objective without requiring metaphysical foundations. The architecture of the web doesn't merely organize knowledge—it builds truth from coherence through sustained pragmatic filtering. Understanding this architectural achievement is understanding truth itself.

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