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The GG-Constitution

Four Axioms and Seven Postulates of the GG-Theory Program, From Which GG-6, BI-6, OGN-5, and GDOS Descend as Theorems

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Abstract

Every theory of nature is built on a foundation, yet that foundation is rarely written down. For three and a half centuries — from Newton through Maxwell, Einstein, and the Standard Model — physics has worked beautifully without making its rules of admissibility explicit, relying instead on a craft tradition passed from textbook to textbook and from supervisor to student.

In this paper, we propose that the next foundational step is to write the constitution down. The GG-Constitution — the foundational charter of GG-Theory (Grand Geometric Theory, equivalently Geometry-Gauge Equivalence Theory) — consists of four axioms — locality and causality, the geometry-gauge equivalence principle, the operational/open extension of that principle to measurement, and a maximum-symmetry minimum-freedom rule — together with seven postulates that turn the axioms into a working filter for admissible scientific claims. Remarkably, the eleven clauses are rigid enough to force, as theorems in the companion papers, the six-dimensional bulk geometry, the four-component anomaly identity that locks gravity to gauge structure, the integer ledger that fixes the electroweak hierarchy, and the open-system boundary law from which quantum mechanics, general relativity, and quantum field theory emerge as four-dimensional projections.

Strikingly, the same four axioms, when applied with different subsets active, locate essentially every major theoretical-physics framework of the twentieth century — general relativity, gauge theory, string theory, AdS/CFT, quantum mechanics, the Standard Model, and ΛCDM — inside a single constitutional tower, and predict which of each framework's famous limitations follow from which axioms it lacks.

After all, what makes a body of knowledge a science is not the cleverness of its calculations but the honesty of its rules.

Executive Summary

Physics runs on rules nobody wrote down. Every working physicist knows what counts as a law, what counts as an observation, and what is allowed to remain an adjustable number. Nobody is taught these things from a document. They are absorbed by apprenticeship, passed from supervisor to student and from textbook to textbook, and they are nowhere written out. Newton's *Principia*, Maxwell's *Treatise*, Einstein's papers of 1905 and 1915, and the Standard Model assembled in the 1960s all rest on such commitments, and none of them states what those commitments are. Later work sharpened particular corners — the decoherence program around measurement, the axiomatic and open-system formalisms around locality and positivity — but no short document was ever produced that a reader could hold in one hand and check a candidate theory against.

What this paper proposes. We propose to write that document. It has eleven clauses: four axioms and seven postulates, fitting on the equivalent of a single page.

The four axioms say what kind of object a physical theory is allowed to be. Causes precede effects and nothing outruns light. The geometry of spacetime and the gauge fields of the forces are one object seen from two angles, not two kinds of thing that happen to coexist. Observation is not a special act performed by a conscious being but a projection — a system with many degrees of freedom being read by an instrument with few. And a theory may not carry an adjustable number unless something forces the number to be there.

The seven postulates say which such theories survive contact with the world. They require that a symmetry holding for one electron still hold for a mole of them; that one variational principle serve rather than several; that the quantum consistency conditions cancel exactly; that probabilities remain probabilities under every allowed evolution; that the answer not depend on how finely one chose to look; that the remaining numbers be integers and simple ratios rather than free decimals; and that every central claim name, in advance, the measurement that would kill it.

A theory is admissible if and only if it satisfies all eleven. That is a checklist, not a mood, and it can be run against any candidate.

Three things that make it different. Prior axiomatizations of physics exist, and this one differs from them in three ways.

It puts measurement on the same footing as causality. In previous axiom systems measurement arrives late, as interpretation laid over a dynamics already complete. Here it is a founding clause, and the awkward pieces of quantum mechanics — the Born rule, the collapse, the pointer basis, the violation of Bell's inequality — become things to be derived rather than assumed.

It forbids unforced adjustable numbers as a rule rather than as a taste. Physicists have always preferred fewer free parameters. Preference is not a constraint, and the free-parameter count of fundamental physics rose through the twentieth century rather than falling. Stated as a clause, the preference becomes a claim that can fail: either the constants of nature descend from something, or the framework is wrong.

It names the measurements that would end it. Among them: a mass cluster near 3.85 TeV, a matter fraction of exactly $1/\pi$, a dark-matter oscillation at one part in thirty-five, and a fixed ratio among the four components of the anomaly. Each is sharp, none was fitted, and any one of them can close the program.

The twentieth century, sorted by the rules it used. The classification that follows from this is the part we would most like a reader to weigh. Instead of asking which theory is right — a question rival frameworks rarely let one settle — one can ask which of the four axioms each framework quietly assumes. The answer sorts essentially all of twentieth-century physics into four layers. One axiom gives special relativity. Two give general relativity, gauge theory, and the classical-topological backbone on which string theory and AdS/CFT are built. Three bring in observation, and quantum mechanics, statistical mechanics, black-hole thermodynamics and the free-energy principle of theoretical neuroscience turn out to share it — four communities that rarely read one another, standing on one clause. The fourth removes the remaining freedom.

What makes this more than a filing system is that it predicts silences. A framework without the operational axiom cannot say when a measurement happens, and historically does not. A framework without the parsimony axiom cannot say why the constants take the values they do, and does not. What a theory *cannot* say is as diagnostic as what it can, and the missing clause tells one which silence to expect.

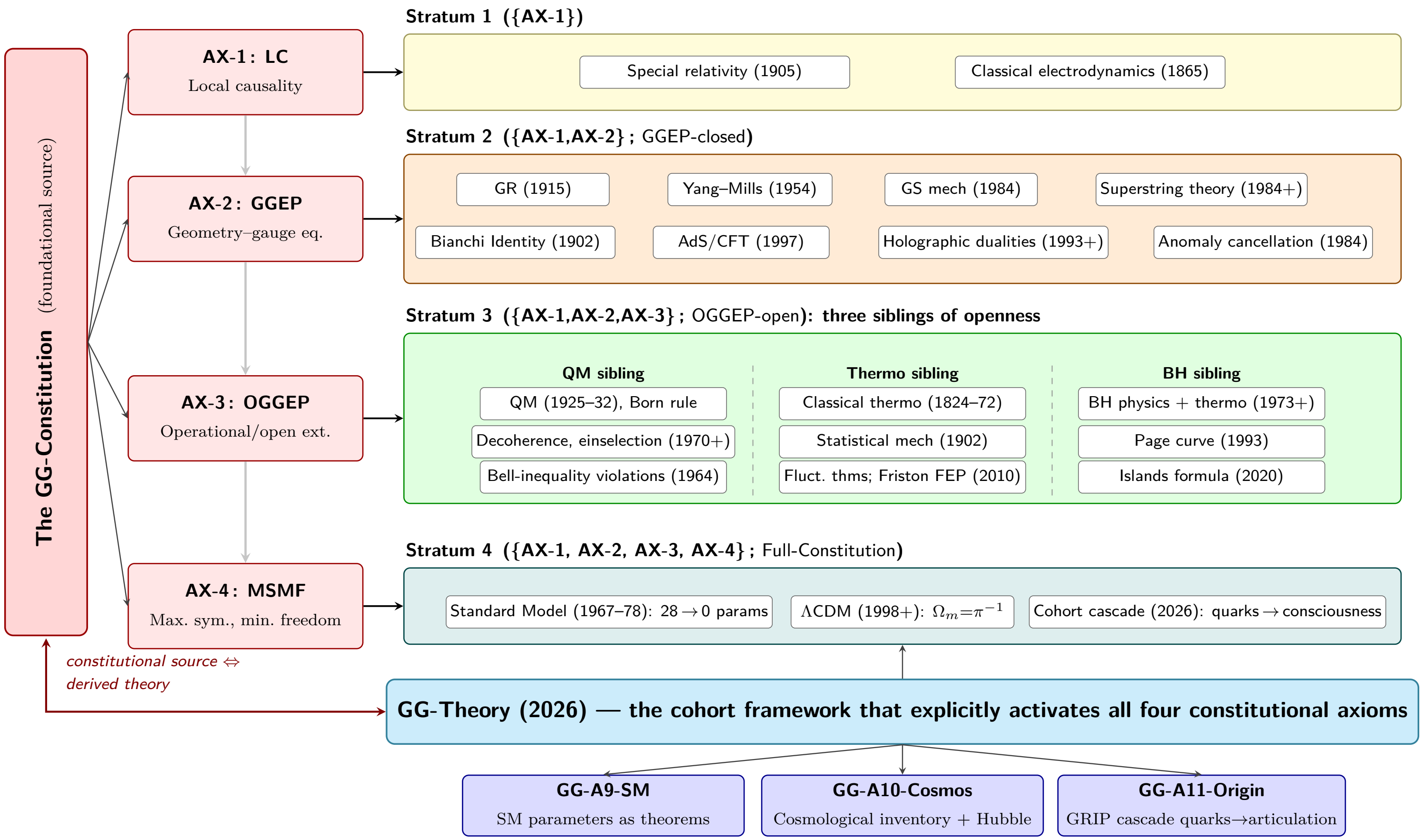
What is established here, and what is not. This paper states the constitution and proves almost nothing. The demonstration that eleven clauses force a six-dimensional geometry, an exact anomaly identity, a five-integer ledger and a boundary law lives in twenty-one companion papers, and every claim here carries the named theorem in the named paper where its proof sits. The numbers are graded rather than announced: of the Standard Model's twenty-eight parameters, the companion work derives six end to end, forces fourteen more once a single named lemma is supplied in each case, and leaves eight asserted with the calculation that would close them named explicitly. That the same clauses reach through chemistry and biology to living matter is the program's central wager, not a theorem of this paper, and is marked as such wherever it appears.

A closing thought. An unwritten rulebook cannot be wrong. It bends quietly around each new result, and nobody has to admit anything. Writing the rules down makes them attackable, and every place the written version fails to match what physicists actually do becomes a visible defect rather than an invisible habit. That is uncomfortable, and it is the reason to do it.

Underneath the technical program lies a question physics never had to answer, because it never wrote down whether the answer was allowed to matter. Either the constants of nature were chosen from a menu, or they are what remained after the constraints had their say — the shape a soap film takes on a wire loop, which it does not select but cannot avoid. We offer this short text in that spirit, and invite the reader to find it wanting.

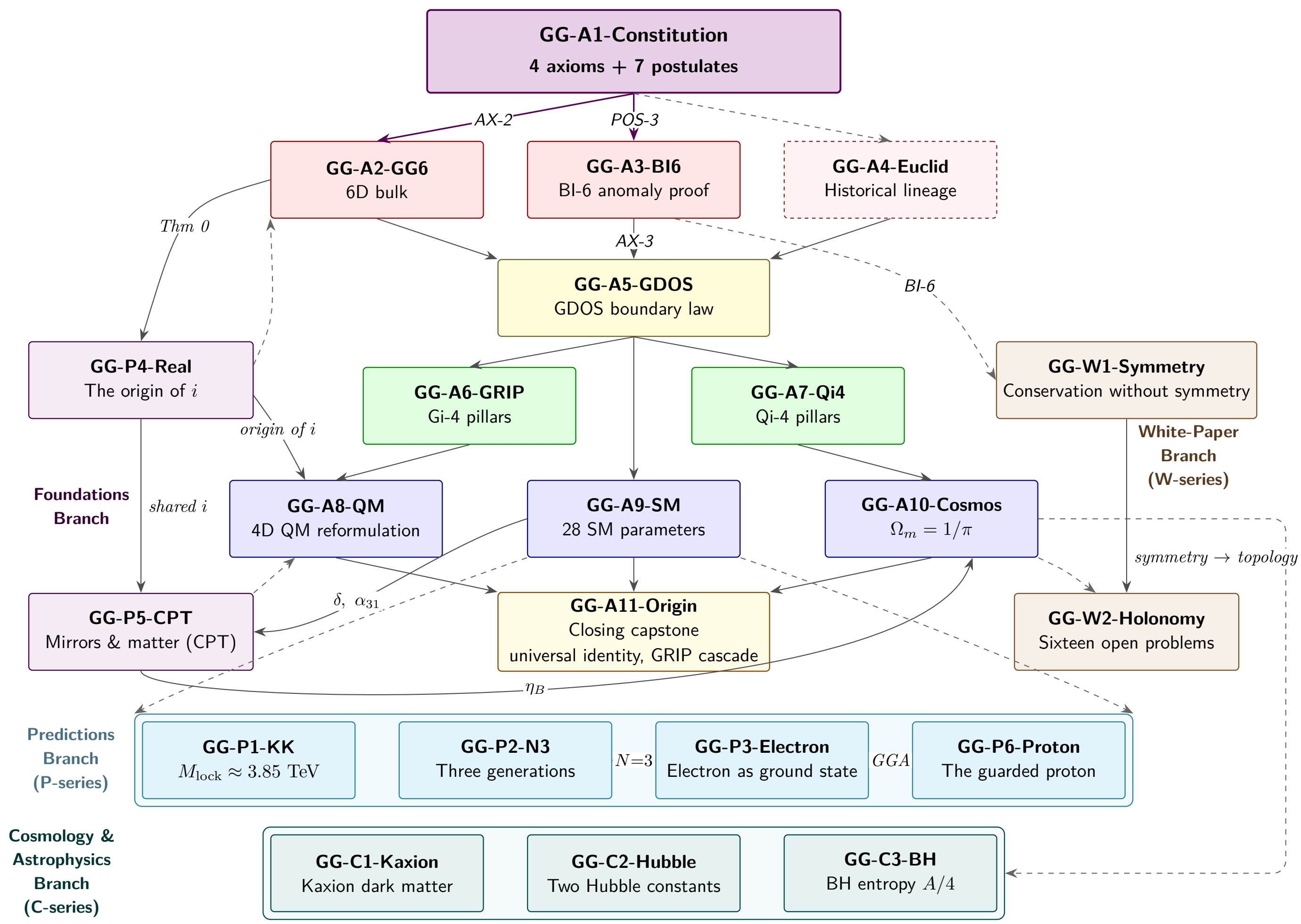
Keywords: GG-Theory; GG-Constitution; four axioms (LC, GGEP, OGGEP, MSMF); seven postulates (GI, UEP, AF, CP, RG, OGN, MF); 6D bulk; BI-6 anomaly identity; OGN-5 integer ledger; GDOS boundary law; Gi-4/Qi-4 pillars; admissibility predicate; falsifiability; geometry-gauge equivalence; CPTP channel; Stinespring dilation; Born rule; Standard Model; ΛCDM.

Every Framework of Twentieth-Century Physics, Sorted by the Axioms It Uses



The constitution drawn as a flowchart. Each framework of twentieth-century physics enters at the level of the axioms it implicitly uses, and the branches descend as axioms are added: one axiom gives special relativity, two give the geometric machinery of general relativity and gauge theory, the third adds the boundary coarse-graining that quantum mechanics and thermodynamics share, and the fourth removes the freedom that remains. What each branch *cannot* say is the content of the chart — a missing axiom is a prediction about which questions a framework will leave open, not merely an omission. Read stratum by stratum, with what each stratum's occupants are unable to express: Figure 10 in Part V, p. 159.

Eleven Clauses, Twenty-Two Papers, No Free Parameters



The twenty-two-paper cohort map of GG-Theory. The constitutional root GG-A1-Constitution (violet, top) supplies the four axioms and seven postulates from which the rest of the cohort descends: the GG6 Trio (GG-A2-GG6, GG-A3-BI6, GG-A4-Euclid, red) realizes the bulk geometry; GG-A5-GDOS (yellow) the boundary law; the GDOS Trio pillars (GG-A6-GRIP, GG-A7-Qi4, green) the geometric and quantum-information runtime; the 4D-Physics Trio (GG-A8-QM, GG-A9-SM, GG-A10-Cosmos, blue) the textbook readouts; and the closing capstone GG-A11-Origin (gold) the quarks-to-consciousness identity cascade. Solid arrows mark axiom-forced descent and carry an edge label naming the driving axiom or postulate; dashed arrows mark the deployment of derived results. The two flanking branches and the full reading conventions are in Figure 3 in Part I, p. 30.

Ten Pre-Declared Numbers, and What Would Kill Each One

Ten pre-declared numbers, and what would kill each one. The sharpest numerical predictions of the GG-Theory program, each with the threshold declared in advance that would falsify it and its experimental status in 2026. Two rows are measured and verified, three are consistent with current data, two are under active experimental search, and three are carried as forward audits. The right-hand column links to the companion paper where the prediction is proved. Proof locations, the comparison mode for each row, and the full claim contracts are in Table 7 in Part IV, p. 152.

Falsifier	GG closed form	Measured, 2026	Status	Dies if	Proved in
F-1 GUT scale $E_{\rm GUT}$	$E_{\rm Pl}e^{-2\pi} \approx 2.28 \times 10^{16}$ GeV	Inferred from α_i flow	Forward audit	Unification fails at one loop	GG-A2-GG6
F-2 Lock cluster $M_{\rm lock}$	$\frac{1}{2}M_{\rm Pl}e^{-35} \approx 3.85$ TeV	No resonance yet at this mass	Active LHC search	5σ absence at HL-LHC, or 5σ resonance at $\neq M_{\rm lock}$	GG-A2-GG6, GG-A9-SM, GG-P1-KK
F-3 Electroweak vev v	≈ 246 GeV	246.220 ± 0.001 GeV	**Verified**	Deviation $> 5\sigma$ from the rational derivation	GG-A9-SM
F-4 Matter fraction Ω_m	$1/\pi = 0.31831$	0.3153 ± 0.0073 (Planck 2018)	$\sim 0.3\sigma$	5σ from $1/\pi$ at resolution $\sigma \leq 0.003$	GG-A10-Cosmos
F-5 CC scale m_Λ	≈ 6 meV	Consistent with $\Lambda \approx 1.1 \times 10^{-52}$ m^{-2}	Consistent	Deviation $> 5\sigma$ from neutrino-scale matching	GG-A10-Cosmos
F-6 Baryon fraction Ω_b	$1/(2\pi^2) = 0.05066$	0.0493 ± 0.0006 (Planck 2018)	$\sim 2\sigma$	5σ in any next-generation BBN / CMB fit	GG-A10-Cosmos
F-7 Kaxion split $\Delta\nu/\nu$	$1/35 = 0.02857$	Not yet registered	Active haloscope search	Narrow peak at $\neq 1/35$ at 5σ	GG-A10-Cosmos, GG-C1-Kaxion
F-8 Generations N	Exactly three families	Three observed	**Verified**	A fourth admissible generation	GG-A2-GG6, GG-P2-N3
F-9 BI-6 trace ratio	$\lvert a/c\rvert = \lvert a/d\rvert = 5/2$	Implied by SM hypercharge via descent	Forward audit	A fifth admissible anomaly polynomial	GG-A3-BI6
F-10 Reality of the bulk category	One shared i; no fundamental non-geometric *CP* phase; no quaternionic Born residue	No anomaly registered	Forward audit	A *CP* phase resisting geometric expression; verified unshared-i interferometry; a 5σ quaternionic Born deviation	GG-P4-Real, GG-P5-CPT

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Preface

Every science begins with rules. Euclid's geometry begins with five postulates that fit on a single page. Newton's mechanics begins with three laws of motion that any high-school student can recite. Maxwell's electrodynamics begins with four equations that fit on a coffee mug. Yet beneath each of these explicit rules lies a deeper layer that has almost never been written down — the meta-rules that say what counts as a law in the first place, what counts as an observation, what is allowed to remain an adjustable knob, what kinds of theories are even admissible candidates for being a theory of nature at all.

These meta-rules exist. Every working physicist knows them. They are passed silently from textbook to textbook, from supervisor to student. A young theorist learns that gauge symmetries must be local, that observables must be Hermitian, that fundamental theories must be Lorentz-invariant, that the variational principle is the right place to start — but none of these meta-rules has ever appeared in a numbered list of axioms that the reader can audit clause by clause. For three and a half centuries the meta-rules have been a craft tradition. A craft tradition is enough to build pyramids; it is not enough to write a constitution.

This paper proposes that the next foundational step in physics is to put the meta-rules in writing. We call the resulting short document the GG-Constitution: four axioms, seven postulates, eleven clauses in total. Small enough that any reader can hold all eleven in mind in a single afternoon. Rigid enough that a single empirical refutation upstream — a verified deviation from one of its sharp numerical predictions — collapses one or more clauses. The bargain offered to the reader is modest in form and radical in content: we ask only that the eleven clauses be accepted as the rules of the game, and then we let physics descend from them as theorems rather than as fits.

We invite the reader to test this document in the spirit Euclid invited his readers to test the *Elements*. Read each clause. Ask whether it is honest. Watch what theorems follow. After all, a constitution earns its name not by the cleverness of the theorems it produces but by the transparency with which it submits to refutation. The first scientific revolution put the rules of geometry in writing. The proposal here is that the next scientific revolution will put the rules of physics in writing — and then submit them to the world.

Part I
Foundations

The Constitutional Question and Why Physics Needs an Axiom Layer After Three and a Half Centuries

Every working laboratory runs on two sets of rules. One is posted on the wall: how to handle the cryogen, who signs the logbook, what counts as a calibration. The other is written nowhere, and it is the more important of the two. It says what counts as a *result*. It says that a measurement nobody can repeat is not yet a measurement; that a model with enough adjustable constants to fit anything has explained nothing; that a theory which cannot be shown to be wrong is not yet physics. Graduate students absorb this second set by watching their supervisors, and almost nobody writes it down.

This Part is about that second set of rules.

We begin with history, because the rules were not handed down all at once — they accumulated, and each one was hard won. Euclid showed that a large body of knowledge could be grown from a short list of stated assumptions. Newton showed that the same few laws govern a falling apple and an orbiting moon. Riemann gave geometry the freedom to curve; Maxwell found that light is a disturbance in a field; Einstein made geometry itself the carrier of gravity; von Neumann put quantum mechanics on a rigorous footing; and the open-systems generation — Zeh, Joos, Zurek, Lindblad, and others — worked out what it means for a system that cannot see everything to make a measurement at all. Each step tightened the informal rulebook. None of them wrote it out.

We then say what we think is missing. Four clusters of problems have resisted the twentieth century's methods: the measurement problem, the unexplained parameters of the Standard Model, the cosmological constant, and the gulf between physics and the sciences of the living. Our diagnosis is that these are not four separate failures of cleverness but one failure of bookkeeping — physics never wrote down which commitments it was actually making.

The rest of the Part is preparation. We fix four words that will be used precisely throughout (*axiom*, *postulate*, *theorem*, *constitution*), preview the eleven clauses that follow, and place this paper inside the twenty-two-paper program it serves as the root of. A reader who wants the whole argument in plain language before any formalism should read Appendix E, which answers twenty-five basic questions without a single equation.

1 Introduction

1.1 A historical chain in seven steps: from Euclid to the open-systems generation

The question we shall ask in Part I is whether the next foundational step in physics is the writing-down of a constitution that has, for three and a half centuries, been carried only in the craft tradition. Before we ask the question rigorously, we ought to walk the historical chain that brought us to this moment. Indeed, every axiomatic move in the long history of physics — from Euclid's *Elements* to the open-systems formalism of the late twentieth century — has been an attempt to turn a tacit body of practice into an explicit document that any later reader could audit line by line. The GG-Constitution proposed in this paper continues that line of work; its novelty sits at one specific link in the chain. Let us trace the seven steps that lead to it.

Step 1. Euclid (*ca.* 300 BCE). The *Elements* of Euclid (c. 300 BCE) is the founding demonstration that a small set of definitions, postulates, and common notions can generate a vast theorem space by a fixed deductive procedure. Euclid did not invent geometry, of course; geometry had been practiced for millennia before him. Yet his contribution was the architecture: an axiom-postulate-theorem pipeline so robust that *any* later reader could reproduce every result by running the deductions on paper, without consulting the master. What makes a body of knowledge a science is not the cleverness of its calculations but the honesty of its rules — and Euclid was the first to write the rules down. The present GG-Constitution is a deliberate echo of that move, applied not to plane geometry but to the rules of admissibility for any candidate theory of nature.

Step 2. Newton (1687). The *Principia Mathematica* of Newton (1687) is the first complete constitution for mechanics. Three laws of motion plus the law of universal gravitation, together with explicit definitions of mass, momentum, and force, suffice to render the motions of the heavens calculable from the same axiomatic stack that governs the falling apple. Newton's most consequential move was not the inverse-square law itself but the constitutional stance — that a single short document could serve as the rulebook for celestial and terrestrial dynamics alike. Where Euclid set the architectural template, Newton showed that the template extends to the physical world.

Step 3. Riemann (1854) and Maxwell (1865). Two parallel developments in the nineteenth century broke the Newtonian frame. Riemann (1854), in his Habilitation lecture *Über die Hypothesen, welche der Geometrie zu Grunde liegen*, declared that the geometry of physical space need not be Euclidean — a proposition that took six decades to find its physical meaning, and that Einstein would eventually use as the mathematical substrate of general relativity. Maxwell (1865), in *A Dynamical Theory of the Electromagnetic Field*, provided the first complete unified-field constitution: four equations that fold electricity, magnetism, and the optics of light into a single coherent picture. Riemann taught us that space itself is a degree of freedom, and Maxwell taught us that a unified field is more than two unrelated fields written together. Both will return as primitives in our constitution: the 6D bulk inherits Riemann's lesson on geometry, and the composite gauge connection inherits Maxwell's lesson on unification.

Step 4. Einstein (1905, 1915) and Noether (1918). Special and general relativity (Einstein, 1905, 1915) constitute the first explicit *invariance constitution* in modern physics: the equivalence principle and general covariance together specify what counts as a physically meaningful statement about spacetime. Einstein's move was axiomatic because it did not propose a new force law; it proposed a new admissibility rule, that the laws of physics must take the same form in every local inertial frame. Noether (1918) sharpened this stance by proving that every continuous symmetry of the action implies a conserved current. The lesson of Einstein and Noether is that invariance principles *are* the deep content of physical law — the equations of motion are corollaries. The GG-Constitution takes this lesson seriously and extends it: the geometry-gauge equivalence principle (AX-2 GGEP) is an invariance principle for the composite geometry-plus-gauge connection on a principal bundle (whose specific structure group is determined as a theorem of the cohort companion GG-A2-GG6 (Arisaka, 2026, A2-GG6), not by the axiom itself), and the operational/open extension (AX-3 OGGEP) is an invariance principle for measurement on the boundary.

Step 5. Heisenberg, Schrödinger, Born, and von Neumann (1925–1932). Quantum mechanics arrived through a remarkable cluster of papers in the late 1920s. Heisenberg (1925) introduced matrix mechanics; Schrödinger (1926) introduced wave mechanics; Born (1926) introduced the probabilistic interpretation that turned the squared modulus of the wave function into a recipe for predicting measurement outcomes. von Neumann (1932) consolidated these threads into the first axiomatic Hilbert-space formulation of quantum theory — the closest thing the early twentieth century had to a written quantum constitution. Yet a single weight-bearing problem remained: the relation between unitary evolution and the projection postulate of measurement was left as a pair of separate rules, with no theorem connecting them. Indeed, every textbook of quantum mechanics for the past ninety years has presented unitary evolution and the Born rule as *independent* axioms — a fact that ought to bother any reader trained in the Euclidean tradition. The GG-Constitution sits at exactly this fault line. Its AX-3 OGGEP promotes the operational map to a primitive object; its T2 (Operational Closure, proved in GG-A5-GDOS (Arisaka, 2026, A5-GDOS)) demonstrates that the Born rule and the GKLS generator follow as theorems rather than as separate assumptions.

Step 6. Partial constitutions for QFT, locality, and open evolution (1955–1982). The middle decades of the twentieth century produced a chain of partial axiomatizations, each of which sharpened a specific layer of physics into an explicit document. Stinespring (1955) proved the dilation theorem that turns every completely positive map into the partial trace of a unitary on a larger Hilbert space. Wightman (1956) gave axioms for relativistic quantum fields that elevated locality and positivity to first-class commitments; Haag (1992) extended the axiomatization to operator algebras on local regions of spacetime. Bell (1964) clarified that local-causality is not a metaphysical optional but an operationally falsifiable constraint, and Aspect, Dalibard, & Roger (1982) verified the predicted violation of Bell inequalities in the laboratory. Wilson (1971) turned coarse-graining itself into a flow on theory space, making scale a first-class concept. Lindblad (1976) and Gorini et al. (1976) classified the admissible Markovian generators of completely positive trace-preserving evolution — the GKLS form. Each of these lines is a partial constitution, sharp on its specific layer but never assembled into a single axiom-postulate document covering all of physics. Roughly speaking, the work of this era gave us all the right ingredients; what was missing was the table on which to lay them out together.

Step 7. The open-systems generation (1970–2003). The decoherence program of Zeh (1970), Joos & Zeh (1985), and Zurek (1981, 2003) accomplished the most consequential shift since von Neumann. Zeh recognized in 1970 that no real system has ever been isolated from its environment — every quantum system in nature is, in fact, an open system. Joos and Zeh in 1985 quantified the staggering speed of environmental decoherence; Zurek in 1981 and 2003 named the mechanism "einselection" and showed that the environment selects a preferred pointer basis on a timescale far shorter than any laboratory observation can resolve. Yet, even so, the open-systems formalism remained a corrective layer added on top of unitary quantum mechanics, not an axiomatic rewrite. Every quantum-mechanics textbook still opens with the closed Schrödinger equation and treats decoherence as a complication that arises later. The GG-Constitution proposes the inversion: openness must be the foundational law, and closure becomes its limiting case. This is the central axiomatic move of the present paper, and it is realized by the elevation of AX-3 OGGEP to the same logical footing as AX-1 LC and AX-2 GGEP.

Where the chain ends and where the present paper begins. Seven steps suffice to bring us to the present moment. Euclid gave us the architecture; Newton showed it applies to physics; Riemann and Maxwell taught us that geometry and unified fields are the right primitives; Einstein and Noether elevated invariance to the deep content of law; the founders of quantum mechanics gave us the Hilbert-space framework but left measurement loaded; the mid-century axiomatizers (Stinespring, Wightman, Bell, Wilson, Lindblad) sharpened individual layers but never assembled them; and the open-systems generation (Zeh, Joos, Zurek) recognized that the inherited foundation had been written upside down. The present paper proposes the eighth step — a single short document, the GG-Constitution, that turns the axiomatic questions implicit in the previous seven steps into four axioms and seven postulates that any reader can audit line by line. Indeed, every later theorem in the GG-Theory program cites this document by name.

1.2 Motivation: an axiomatic gap after the twentieth-century revolutions

The twentieth century produced two foundational revolutions — quantum mechanics and relativity — that reshaped the meaning of state, symmetry, and prediction. Quantum theory emerged from the early quantum hypothesis and the subsequent development of matrix and wave mechanics (Born, 1926, Heisenberg, 1925, Planck, 1900, Schrödinger, 1926). Relativity recast spacetime as a geometric object and reinterpreted gravity as curvature (Einstein, 1905, 1915). These achievements were consolidated into robust theory stacks: quantum field theory (QFT), the Standard Model (SM), and precision cosmology. Gauge symmetry and renormalization became the workhorses of particle theory (Noether, 1918, 't Hooft, 1971, Wilson, 1971), while cosmic observations established a precise phenomenological expansion history (Guth, 1981, Linde, 1982, Perlmutter et al., 1999, Planck Collaboration, 2018, Riess et al., 1998).

Yet, despite this dramatic success, several deep problems have remained resistant for decades. The point of departure of GG-Theory is a specific diagnosis — the resistance is not only technical; it is also *constitutional*. By an *axiomatic layer* we mean the minimal set of foundational commitments that specify what counts as a law, what counts as an observation, what degrees of freedom are admissible as fundamental, and which free choices (parameters, normalizations, conventions) are allowed to remain as non-derivable input. This paper proposes an explicit axiom/postulate system intended to serve as exactly that layer.

The axiomatic gap can be made concrete by a simple thought experiment. Let us imagine that we are given an equation of motion and a Hilbert-space state. Without additional clauses, we still cannot answer four basic questions that every scientific account must answer. First, which variables are physically redundant ("gauge") and which are physical? Second, which operations count as legitimate observations, and how are they represented mathematically? Third, which parameters are inputs rather than outputs? Fourth, which coarse-grainings are allowed without changing the truth value of a claim? Twentieth-century physics answers these questions implicitly and differently in different subfields: QFT relies on locality, microcausality, and renormalization; measurement theory relies on external instruments and an observer cut; cosmology relies on effective parameters that fit data. The result is not inconsistency in practice, but *axiomatic drift* — admissibility rules are learned as craft rather than stated as law.

The aim of GG-Theory is therefore modest in one sense and radical in another. It is modest because it does not begin by proposing a new Lagrangian or a new particle sector. It is radical because it makes admissibility clauses explicit and insists that they apply across domains. In this paper, "unification" means a single logical pipeline — symmetry, consistency, operational semantics, scale robustness, and falsifiability — used to judge candidate explanations in particle physics, chemistry, biology, and beyond. The constitution is intended as the infrastructure on which the companion papers on GG-6 (Arisaka, 2026, A2-GG6), BI-6 (Arisaka, 2026, A3-BI6), GDOS (Arisaka, 2026, A5-GDOS), Gi-4 (Arisaka, 2026, A6-GRIP), and Qi-4 (Arisaka, 2026, A7-Qi4) build their technical machinery.

1.3 Four clusters of unsolved problems

The axiomatic gap manifests itself in four clusters of unsolved problems — one for each foundational discipline of contemporary physics. We name them in turn.

Cluster (i): quantum mechanics — measurement, openness, and operational meaning. Standard quantum theory combines unitary evolution with a separate set of rules for measurement (the Born rule, the projection postulate, the von Neumann cut) (Born, 1926, von Neumann, 1932). In practice every measurement involves devices, environments, coarse-graining, and irreversible records. Open quantum systems provide the modern operational language — CPTP maps and GKLS generators (Breuer & Petruccione, 2002, Gorini et al., 1976, Lindblad, 1976) — but the formalism is treated as an effective framework rather than as an axiomatic requirement. Every quantum-mechanics textbook for the past ninety years opens with the closed Schrödinger equation and treats decoherence as a complication that arises later (Joos & Zeh, 1985, Zeh, 1970, Zurek, 1981, 2003). What, then, is a measurement? And how shall we write it as a law-like component of a theory rather than as meta-language pasted onto the side?

Cluster (ii): gravity and quantum theory — "quantize geometry" versus "geometrize quantum." The dominant strategy for quantum gravity has been to start from classical geometry (GR) and attempt to quantize it, either perturbatively or non-perturbatively, including the string-theoretic UV completions (Green and Schwarz, 1984, Polchinski, 1995, Rovelli, 2004). In parallel, the gauge/gravity duality program suggests a structural relation between gravity and gauge dynamics (Maldacena, 1998, Susskind, 1995, 't Hooft, 1993, Witten, 1998). These developments raise an axiomatic question: is "quantize geometry" the right starting line at all? The GG-Theory stance reverses the emphasis — it asserts a *geometrization of quantum and gauge structure* at the level of the primitive composite connection (AX-2 GGEP), with quantization treated as an operationally defined boundary manifestation (AX-3 OGGEP).

Cluster (iii): unification and predictivity — too many dials and too many landscapes. The Standard Model is remarkably rigid once its symmetry group and field content are fixed, yet it contains roughly 28 numerical parameters not predicted from first principles (Particle Data Group, 2024). Beyond-the-SM model building typically introduces further tunable sectors; cosmology relies on parameterized fits to large datasets (Planck Collaboration, 2018); and the naturalness debates articulate the concern that small numbers and large hierarchies appear unstable unless protected by principle (Susskind, 1979, THooft, 1980). Many UV frameworks admit very large spaces of consistent vacua, which makes it unclear which features are predictions and which are choices (Polchinski, 2004). The situation is not that the Standard Model is wrong — it is that nobody has yet written down a constitution rigid enough to force its parameters from above. GG-Theory responds by introducing an explicit axiom (AX-4 MSMF) and a postulate (POS-6 OGN) designed to forbid hidden continuous knobs and to force normalization choices into a minimal discrete ledger.

Cluster (iv): cosmology and complexity — fragmentation across sciences. Cosmology raises further unresolved questions: the origin of inflation, the nature of dark matter and dark energy, and the link between microphysics and initial conditions (Guth, 1981, Linde, 1982, Perlmutter et al., 1999, Riess et al., 1998). Beyond fundamental physics, chemistry, life science, neuroscience, and social systems are dominated by open-system dynamics, multi-scale coarse-graining, and inference from incomplete data. Even when micro-laws are known, the effective laws governing the boundary descriptions appear ad hoc. Interestingly, the same admissibility grammar — symmetry, consistency, operational observables, scale covariance, and falsifiability — threads through all four clusters. The ambition of GG-Theory is not to reduce all sciences to particle physics; it is to write down a single admissibility grammar that applies uniformly across domains, so that a chemist, a neuroscientist, and a particle theorist may run the same audit on their respective models.

1.4 Why "axioms plus postulates" — and why now?

Axiom systems are not a matter of style. They are a compression technology. Section 1.1 walked the historical chain from Euclid through the open-systems generation; let us now extract the methodological lesson from that chain. Indeed, every step of the chain produced a *partial* constitution, sharp on its own layer of physics but never assembled into a single document. Special and general relativity gave us an invariance constitution (the equivalence principle and general covariance) (Einstein, 1905, 1915). Axiomatic QFT pushed locality and positivity into explicit axioms (the Wightman and Haag-Kastler frameworks) (Haag, 1992, Streater & Wightman, 1964, Wightman, 1956). Open quantum systems introduced a strict notion of admissible evolution (the completely positive semigroups of GKLS) (Gorini et al., 1976, Lindblad, 1976). And modern renormalization made scale a first-class concept by turning the operation of "zooming out" into a flow on theory space (Wilson, 1971). What is missing from this list is not ingredients — the ingredients are all here — but a *unified ordering and dependency chain*: which clauses are primitive, which are derived, and which are non-negotiable when we cross from closed microscopic descriptions to open boundary observations and from physics to other sciences.

The GG-Constitution responds with a specific architectural choice. Axioms fix the semantic primitives — what objects exist, what counts as redundancy or gauge, what is forbidden as acausal — and postulates act as ordered admissibility filters that any candidate dynamics must pass before it is even up for review (consistency, positivity, scale coherence, normalization, empirical auditability). This separation mirrors the successful practice of physics: we typically reason with invariance and structure first, and only then choose model-specific details. The novelty here is to *freeze* that practice into a portable document that can be applied uniformly to particle models, cosmological models, chemical reaction networks, and biological open systems. What makes a body of knowledge a science is not the cleverness of its calculations but the honesty of its rules.

1.5 Working definitions: axiom, postulate, theorem, and constitution

To avoid terminological drift across the ten Parts of this paper, let us fix the working definitions we shall use throughout. The four definitions are intentionally Euclidean in spirit — short, declarative, and reusable as building blocks — and they are the only definitions we shall need at the axiomatic level.

Definition 1 (Axiom)**.** An *axiom* is a foundational statement that fixes the semantic primitives of the framework: what structures exist, what counts as redundancy (gauge/representation), and what is forbidden (e.g. acausal operational kernels). Axioms are not derived within the framework; they are the minimal commitments that define admissibility.

Definition 2 (Postulate)**.** A *postulate* is an ordered operational admissibility filter that constrains candidate models within the axioms. Postulates typically enforce mathematical consistency (e.g. anomaly cancellation), physical admissibility (e.g. positivity and normalization of states), scale robustness (RG compatibility), and empirical auditability (measurement protocols and falsifiers).

Definition 3 (Theorem)**.** A *theorem* is a derived result forced by axioms and postulates plus explicitly declared assumptions of a concrete model instance. In the GG-Theory style, theorems are expected to ship with an operational contract: a map to registered observables and a pre-declared falsifier.

Definition 4 (Constitution)**.** The *constitution* is the frozen union of axioms and postulates:

$$\text{Constitution} := \{\text{AX}\} \cup \{\text{POS}\}. \tag{1}$$

Grades: how strongly a claim is held. Throughout this paper and the cohort, every substantive claim carries a *grade* saying how far it has actually been established. There are four, and they are ordered:

- **Derived** — forced by the stated clauses through a proof that exists, with no continuous freedom left anywhere in the chain.
- **Conditional** — forced once one further named lemma is supplied. The lemma is stated, and the work it still needs is named.
- **Candidate** — proposed and internally consistent, with the constitutional pricing stated but not proved.
- **Open** — neither proved nor priced; recorded so that it is not mistaken for either of the two above.

A related word, used in the same spirit, is *custody*: where two clauses could each plausibly own a piece of structure, we say which one does, so that no result is quietly claimed twice. Grades and custody are bookkeeping rather than rhetoric. Their whole purpose is that a reader can tell, at any point in the document, the difference between what has been shown and what has been proposed.

1.6 A preview of the GG-Constitution: four axioms and seven postulates

The GG-Constitution comprises four axioms (AX-1–AX-4) and seven postulates (POS-1–POS-7). We state them here informally so that the reader carries them in mind through the rest of Part I; Parts II and III provide the rigorous kernels, parameter definitions, and forced-consequence chains.

Four axioms.

AX-1. LC (Locality and Causality). Admissible evolution is local and causal in the operational sense: boundary updates are retarded, and no acausal effective kernels are permitted.

AX-2. GGEP (Geometry-Gauge Equivalence Principle). The primitive field of physics is a single composite geometry-plus-gauge connection on a principal bundle: quantum and gauge structure are geometrized rather than appended. This is the generalization of Einstein's Equivalence Principle from gravity alone to the full geometry-plus-gauge structure.

AX-3. OGGEP (Operational/Open GGEP). Observation and measurement are defined by a bulk-to-boundary registration map that produces operational observables. Openness is constitutional; closure is its limiting case.

AX-4. MSMF (Maximum Symmetry, Minimum Freedom). Nature selects maximal symmetry with minimal free parameters; continuous dials not forced by the constitution are forbidden, and where discrete choices remain admissible Nature picks the minimal-rational ledger.

Seven postulates.

POS-1. GI (Gauge Invariance). Gauge invariance is layered across scales — local (LGI), dynamical/open (DGI), global (GGI).

POS-2. UEP (Unified Extremal Principle). A single variational engine governs dynamics, unifying least action with least-time and free-energy descent on the boundary.

POS-3. AF (Anomaly Freedom). Admissible theories must cancel every gauge and gravitational anomaly, including by Green-Schwarz inflow (Green and Schwarz, 1984).

POS-4. CP (Closure and Positivity). State evolution must remain physical: CPTP at the quantum level and positivity-preserving Markov semigroups at the classical mesoscopic level.

POS-5. RG (Scale Covariance). Coarse-graining must commute with the operational dictionary; predictions are stable under resolution changes (Wilson, 1971).

POS-6. OGN (Occam Gauge Normalization). Among consistent normalizations, Nature selects minimal rational and integer choices; no arbitrary continuous rescaling survives.

POS-7. MF (Measurement and Falsifiability). Every claim must map to a registered observable and a pre-declared kill criterion.

The admissibility predicate. For any candidate theory T, we define the admissibility predicate

$$\boxed{\text{Admissible}(T) \;:=\; \big(T \models \{\mathsf{AX\text{-}1}, \mathsf{AX\text{-}2}, \mathsf{AX\text{-}3}, \mathsf{AX\text{-}4}\}\big) \;\wedge\; \big(T \models \{\mathsf{POS\text{-}1}, \ldots, \mathsf{POS\text{-}7}\}\big).} \tag{2}$$

The purpose of this paper is to specify the four axioms and the seven postulates with enough precision that (2) becomes a practical filter rather than a slogan, and that any candidate theory can be audited against the predicate clause by clause.

1.7 The geometrization ladder: from Einstein to GG-Theory

The second axiom above (AX-2, GGEP) was described as the generalization of Einstein's equivalence principle from gravitation to the full geometry-plus-gauge content of physics. That phrase deserves to be unfolded once, because it locates the whole program on a single line of descent. Every foundational advance in our picture of spacetime has shared one logical shape — *a physical necessity that earlier theory carried as an external structure is recognized as geometry and absorbed into the manifold or its connection* — and GG-Theory does not introduce this move but completes it. The invariant speed of light was geometrized into a single Lorentzian spacetime, in which c is the conversion factor that fuses space with time (Einstein, 1905, Minkowski, 1908); the equivalence of inertial and gravitational mass was geometrized into the curvature of that spacetime, so that gravity became the shape of the stage rather than a force upon it. Two further necessities, unknown to Einstein, complete the ladder: the local gauge phase, recognized as a connection whose curvature is the field strength (Kaluza, 1921, Klein, 1926, Yang and Mills, 1954), and the renormalization scale, recognized through Wilson's renormalization group (Wilson, 1971) and the renormalization scale as displacement along a radial direction.

GGEP is the single rule that runs all four rungs to completion: *any structure the dynamics is forced to carry must be realized geometrically.* Applied to a local, causal, interacting, charged quantum theory, it geometrizes exactly two necessities beyond the Lorentzian stage — a scale and a phase — and closes there, yielding a six-dimensional arena $\mathcal{M}_4 \times I_r \times S^1_\theta$ that can be neither smaller nor larger. These two directions are also the source of the only two transcendental constants the framework will admit: e, the base of every exponential along the scale interval I_r, and π, the angle of the gauge circle S^1_θ — so that in every later formula an exponential is a scale factor and a π is a gauge holonomy or a volume. The point of method worth carrying through the rest of this Constitution is that the extra dimensions of GG-Theory are not postulated, as spatial extra dimensions must be, but *derived* as the geometrization of two things any such theory already cannot avoid; and that the program thereby completes the geometric unification Einstein pursued for thirty years, by enlisting the two quantum-field-theoretic ideas — the gauge principle and the renormalization group — that postdated him and that he would likely have resisted. The formal version of this claim is Theorem 0 of the companion paper (Arisaka, 2026, A2-GG6), which proves that AX-1 and AX-2 alone force the six-dimensional bulk; the present paper supplies the constitutional clauses on which that proof draws.

The constitutional picture in one diagram. The same geometry can be read a second way that the rest of this Constitution uses repeatedly, and Figure 1 fixes it once. The six-dimensional arena is a *fiber bundle*: its base is the Lorentzian stage $\mathcal{M}_4$ on which observations are registered, and over every point of that stage sits a two-part *non-spatial* fiber — the scale interval I_r and the phase circle S^1_θ. Two axioms act on this one object in opposite directions. AX-2 (GGEP) *builds* the fiber: it is the rule that the two unavoidable necessities of a local, causal, charged quantum theory — a renormalization scale and a gauge phase — must be realized as geometry, and so brings the two fiber directions into being. AX-3 (OGGEP) *collapses* it: registration on the boundary is the projection π that erases the fiber coordinates, because neither is a direction of space and neither can be resolved by any boundary protocol. The downward arrow is the origin of quantum behavior — superposition and interference are the unread phase S^1_θ, while measurement and its irreversibility are the coarse-grained scale I_r — which the companion paper (Arisaka, 2026, A8-QM) develops in full; the upward arrow is the bulk derivation of (Arisaka, 2026, A2-GG6). The whole program lives between these two arrows: GGEP constructing the bulk above the stage, OGGEP projecting it back down to the observed world.

2 This paper's place in the cohort: one link of the open-system chain

The constitution developed in this paper stands on its own: it fixes what counts as an admissible law, an admissible observation, and an admissible prediction in any candidate physical theory. For readers following the whole GG-Theory cohort, it is also one link of a single open-system chain that

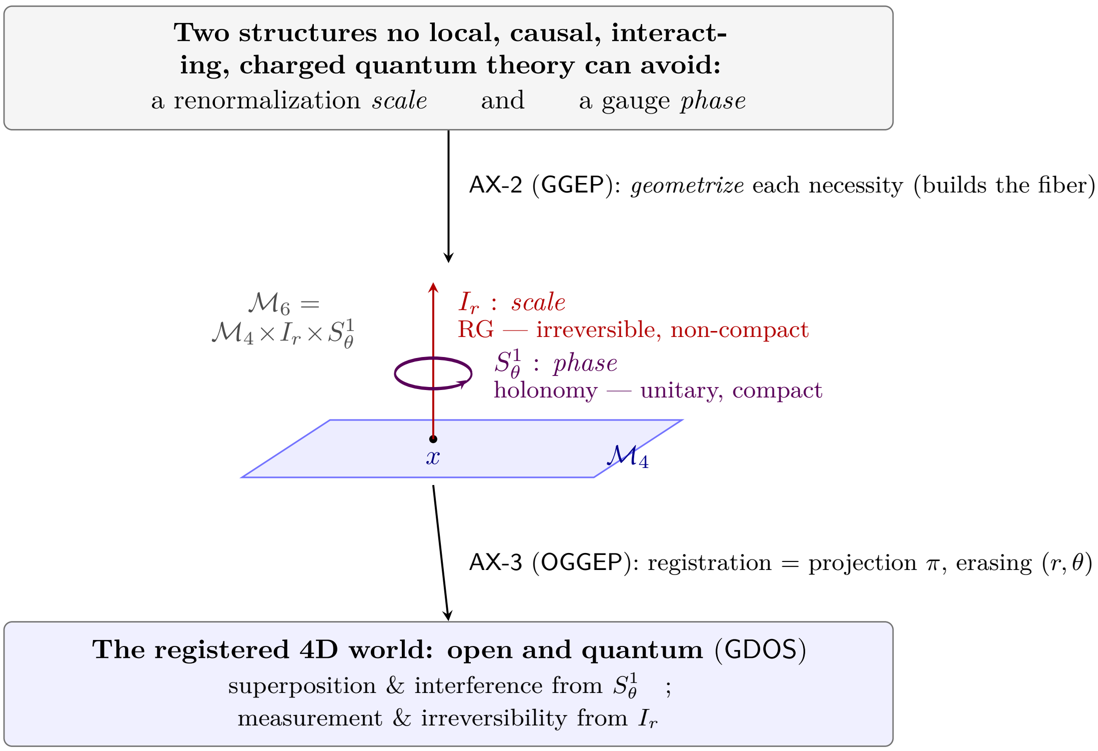

Figure 1: The program in one diagram. The six-dimensional bulk is a fiber bundle over the Lorentzian stage $\mathcal{M}_4$, carrying at each point the two non-spatial fibers I_r (scale) and S^1_θ (phase). AX-2 (GGEP) acts *upward*: it geometrizes the two necessities a local, causal, charged quantum theory cannot avoid, bringing the fibers into being (the bulk derivation, Theorem 0 of (Arisaka, 2026, A2-GG6)). AX-3 (OGGEP) acts *downward*: registration on the boundary is the projection π that erases the fiber, which is the origin of quantum behavior — the compact phase S^1_θ supplying coherence and interference, the non-compact scale I_r supplying measurement and its irreversibility (the open-system law GDOS, developed in (Arisaka, 2026, A8-QM)). The whole program lives between these two arrows.

the consequence papers cash out. Because no physical system is closed, the four-dimensional world is a lawful projection (OGGEP) of the six-dimensional bulk, and that projection is observation itself; its dynamics is the boundary law GDOS, forced by the geometric Gi-4 and quantum-information Qi-4 pillars, so that the laws, the particles, and the contents of the universe are *observables* of the projection rather than free inputs. In that chain, the present paper supplies the constitution itself — including its third axiom OGGEP (AX-3), the projection on which the whole chain depends. The funnel below is shared, in structure, with the companion papers GG-A9-SM, GG-A10-Cosmos, and GG-A11-Origin; here it is offered only as orientation, and the rest of this paper proceeds on its own terms.

Figure 2 places the present paper inside that chain: the funnel it draws is the one every cohort paper enters, and what this one contributes to it is the constitution itself and the operational axiom AX-3.

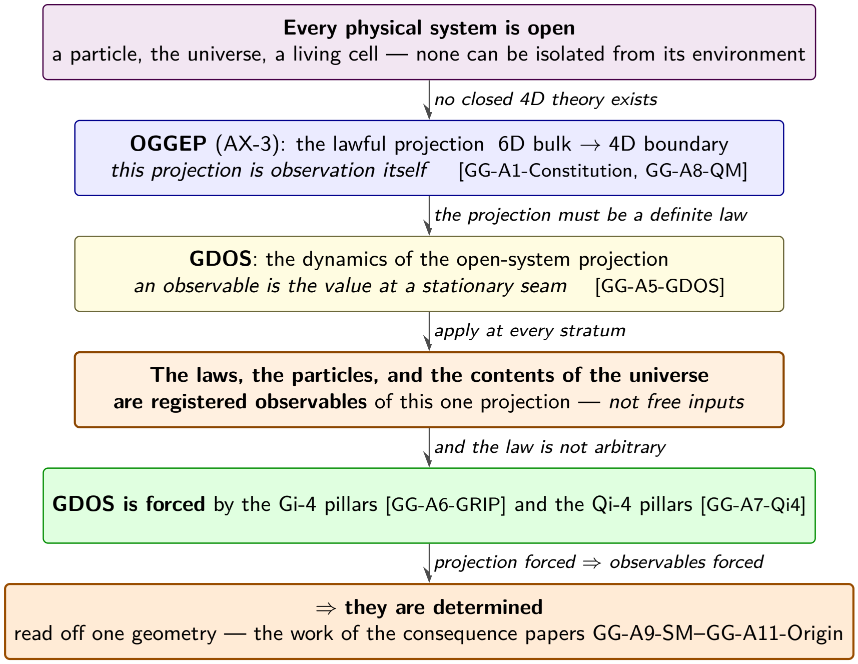

Figure 2: The open-system chain shared across the GG-Theory cohort. Because no physical system is closed, the four-dimensional world is a lawful projection (OGGEP, AX-3) of the six-dimensional bulk, and that projection is observation itself; its dynamics is GDOS, forced by the Gi-4 and Qi-4 pillars, so the laws and contents of the universe are observables rather than free inputs. The same funnel opens the consequence papers GG-A9-SM, GG-A10-Cosmos, and GG-A11-Origin, with a paper-specific payload; within it the present paper establishes the constitution and its axiom OGGEP (AX-3).

3 The cohort inheritance and the roadmap of the ten Parts

Before we descend into the four axioms (Part II) and the seven postulates (Part III), it is useful to lay out two reader-orientation maps on the same opening: a panorama of the twenty-two-paper cohort that the GG-Constitution compiles into (§3.1, **Figure 3**), and a panorama of the ten Parts of the present paper (§3.2, **Figure 4**). A reader of any later Part should be able to flip back to this Section and orient themselves in both directions: which cohort companion carries which Principal Theorem, and where the present argument stands in the ten-Part arc. After all, the constitution is the entry point the broader physics community will reach first; this Section is the "you are here" map that an entry-point paper owes its readers.

3.1 The cohort inheritance

The GG-Constitution is the axiomatic root of a twenty-two-paper research program: eleven A-papers, six P-papers, three C-papers and two W-papers, the P-series carrying both the phenomenology preprints (P1–P3, P6) and the two foundations members (P4–P5). The constitution stays short — four axioms and seven postulates — precisely because the working machinery lives in the cohort companions; the constitution names the rulebook against which each companion's theorems are audited. Roughly speaking, the A-series inheritance falls into five strata: the constitutional root (GG-A1-Constitution), the GG6 Trio (GG-A2-GG6, GG-A3-BI6, GG-A4-Euclid: bulk geometry), the boundary law (GG-A5-GDOS) with its two sibling pillars (GG-A6-GRIP, GG-A7-Qi4), the Consequence Trio (GG-A8-QM, GG-A9-SM, GG-A10-Cosmos: textbook readouts), and the closing capstone (GG-A11-Origin). On the spine's left flank, the Foundations Branch (GG-P4-Real, GG-P5-CPT) carries the origin of the boundary's complex structure and the discrete-symmetry/matter interface; on the right flank, facing it, the White-Paper Branch (GG-W1-Symmetry, GG-W2-Holonomy) carries the two syntheses that read the cohort rather than extend it. Beneath the cohort, the Predictions Branch (GG-P1-KK, GG-P2-N3, GG-P3-Electron, GG-P6-Proton) and the Cosmology & Astrophysics Branch (GG-C1-Kaxion, GG-C2-Hubble, GG-C3-BH) supply sharp phenomenological falsifiers. The single most useful visual orientation is the inheritance map of **Figure 3**; the per-paper paragraphs below give the constitutional content carried by each node.

GG-A1-Constitution — The GG-Constitution (this paper). Four axioms (AX-1 LC, AX-2 GGEP, AX-3 OGGEP, AX-4 MSMF) and seven postulates (POS-1 GI, POS-2 UEP, POS-3 AF, POS-4 CP, POS-5 RG, POS-6 OGN, POS-7 MF) plus the admissibility predicate Admissible(T) that any candidate theory must satisfy. The eleven Principal Theorems T1–T11 are named here at high level; their proofs live in the cohort.

GG-A2-GG6 — GG-6: Geometry-Gauge Locking at 6D bulk (Arisaka, 2026, A2-GG6). Forced by AX-2 GGEP together with POS-3 AF, POS-5 RG, and POS-6 OGN. The companion paper constructs the canonical 6D bulk $ds_6^2 = e^{-2r}\eta_{\mu\nu}dx^\mu dx^\nu + dr^2 + d\theta^2$ with $r \in [0, K]$ and $\theta \in [0, 2\pi)$, and proves that this bulk is the unique anomaly-free, moduli-free solution to the axiomatic constraints. Principal Theorems T1, T3, T4, and T6 live there.

GG-A3-BI6 — BI-6: the Green-Schwarz-modified Bianchi identity for GG-6 (Arisaka, 2026, A3-BI6). Forced by POS-3 AF on the 6D bulk. The companion paper supplies the rigorous Hopkins-Singer differential-cohomology proof that the four-component anomaly polynomial $X_4 = \mathrm{tr}(R \wedge R) - \mathrm{tr}(F_{\mathrm{SU}(5)} \wedge F_{\mathrm{SU}(5)}) - \frac{2}{5} F_B \wedge F_B - \frac{2}{5} F_{Qi} \wedge F_{Qi}$ is exact, with the geometry-gauge trace-ratio lock $|a/c| = |a/d| = 5/2$. Principal Theorem T5 lives there.

GG-A4-Euclid — From Euclid to GG-6: the historical lineage (Arisaka, 2026, A4-Euclid). The pedagogical companion to the GG6 Trio. Traces the long chain from Euclid's *Elements* through Newton, Riemann, Maxwell, and Einstein to the 6D bulk of GG-6. No new theorems; the role is to position the cohort framework against its predecessors and to keep the historical audit honest.

GG-A5-GDOS — GDOS: Geometric Dynamics of Open Systems (Arisaka, 2026, A5-GDOS). Forced by AX-3 OGGEP together with POS-4 CP. The boundary-side companion to the cohort. Develops the canonical boundary law $\mathcal{L}_{\mathsf{GDOS}}$ as the unique CPTP generator compatible with the bulk-to-boundary functor, and proves that the textbook QM postulates are theorems of the operational dictionary (the chain T7.1–T7.7). Principal Theorems T2, T7, T8, and T9 live there. GG-A5-GDOS's Part VIII is also the technical home of the constitutional-axiom classification of the twentieth century that Part V of the present paper restates in summary form.

GG-A6-GRIP — The Gi-4 Pillars (Arisaka, 2026, A6-GRIP). Forced by AX-3 OGGEP on the geometric side. The companion paper formalizes the four geometric-invariance pillars descending from the constitution: the Total Geometric-Gauge object TGG, the Covariant Conservation Identity CCI, the Geometric Free-Energy Functional GFF, and the Gauge-Runtime Invariance Pipeline GRIP (the cascade DGI $\to$ GSSB $\to$ GA/GGA, run in the two regimes GRIP-In/GRIP-Out). Principal Theorem T10 lives there. The lineage is stated as Derivation 4 of Section 7: OGGEP demands the dictionary, GDOS writes it, GRIP runs it.

GG-A7-Qi4 — The Qi-4 Pillars (Arisaka, 2026, A7-Qi4). Forced by AX-3 OGGEP on the quantum-information side. The companion paper formalizes the four QI admissibility pillars: Qi-QUA (qua-state preparation), Qi-EP (quantum equivalence principle), Qi-CON (decoherence and contraction), and Qi-HAL (holographic alphabet). Principal Theorem T11 lives there.

GG-A8-QM — 4D Quantum Mechanics in the language of GG-Theory (Arisaka, 2026, A8-QM). The QM stratum of the Consequence Trio. Operationalizes T2 Operational Closure and T7 4D Quantum Mechanics into a concept-by-concept reformulation of textbook QM: the Born rule as a theorem of the Stinespring dilation, EPR / Bell / CHSH / Aspect / Hensen / Giustina as evidence of the non-invertibility of the 6D-to-4D projection, Schrödinger's cat as a boundary decoherence statement, and the central thesis that Einstein was right in 6D and Bohr was right in 4D, each within their respective domains.

GG-A9-SM — The Standard Model parameters from GG-6 (Arisaka, 2026, A9-SM). The SM stratum of the Consequence Trio. Derives the 28 free continuous parameters of the Standard Model — the gauge couplings, the Yukawa couplings, the CKM/PMNS mixing angles, the electroweak vacuum expectation $v \approx 246$ GeV, the cosmological-constant scale $m_\Lambda \approx 6$ meV, and the GG-6-lock-mass cluster $M_{\text{lock}} \approx 3.85$ TeV — from the 6D bulk and the OGN-5 integer ledger. Zero free continuous parameters at the cohort level.

GG-A10-Cosmos — ΛCDM cosmology from GG-6 (Arisaka, 2026, A10-Cosmos). The cosmology stratum of the Consequence Trio. Derives the cosmological inventory partitions $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$, $\Omega_b = 1/(2\pi^2)$, and $\Omega_{\text{DM}} = 1/\pi - 1/(2\pi^2)$ from the 6D bulk and the cohort axioms. Each partition is a discrete consequence of the constitution rather than a fitted dial.

GG-A11-Origin — the closing capstone (Arisaka, 2026, A11-Origin). The recursive-uniqueness companion that closes the cohort. Develops the universal-identity insight (why every electron is the same electron) and the GRIP cascade through atoms, molecules, ATP, DNA, and the first cell. Remarkably, the same OGN-5 ledger that fixes the SM parameters also threads through the chain that produces life, consciousness, and the broader cosmos-life-mind unification.

Predictions Branch and Cosmology & Astrophysics Branch. Beneath the cohort sit the seven short falsifier papers of the two phenomenology branches. The Predictions Branch: GG-P1-KK (the Kaluza-Klein lock-mass cluster at $M_{\text{lock}} \approx 3.85$ TeV, with explicit LHC and future-collider falsifiers), GG-P2-N3 (the three-generation structure forced by the integer ledger), and GG-P3-Electron (the electron as the unique ground state of its boundary stratum, importing GG-P2-N3's $N = 3$ with its fences), and GG-P6-Proton (the proton as the ground attractor of the baryonic stratum, its stability a theorem rather than an accident). The Cosmology & Astrophysics Branch: GG-C1-Kaxion (the kaxion dark-matter oscillation at $\Delta\nu/\nu = 1/35$, with explicit haloscope and microwave-cavity falsifiers), GG-C2-Hubble (the Hubble tension read as the two ends of one six-dimensional geometric corridor), and GG-C3-BH (black-hole entropy with the exact Bekenstein–Hawking coefficient $A/4$ from induced gravity). Each is a sharp falsifier of an upstream cohort theorem.

GG-P4-Real — the origin of i (Arisaka, 2026, P4-Real). The first member of the Foundations Branch, on the map's left flank. Derives the complex numbers of physics from two real structures of the 6D bulk. The compact phase circle S^1_θ, inherited from GG-A2-GG6's Theorem 0 arena, forces the gauge i: its quarter-turn is the unique circle-compatible complex structure on every charged sector (T-P4-1). The causal clock's one-sided spectrum forces the state-space i: the polar phase of the time generator is the unique positive-energy, dynamics-commuting complex structure (T-P4-2). The antiparticle handshake is their forced agreement — the two quarter-turns act as one complex structure on shell precisely under the Feynman–Stückelberg pairing, so antiparticles are derived as a consistency condition rather than postulated (T-P4-3). The bridge theorem then establishes that positive frequency *is* holomorphy, at the Hardy, forward-tube, and twistor levels (T-P4-6/7); the derivations hold at the quasi-free grade, with the interacting extension stated conditionally under its named hypotheses. What descends from this node: the standalone development behind GG-A8-QM's real-bulk series, and the complex-structure machinery the boundary papers consume.

GG-P5-CPT — the mirrors and the matter (Arisaka, 2026, P5-CPT). The second member of the Foundations Branch. Derives the discrete symmetries as orientation: C, P, and T are the orientation reversals of the three real factors of the bulk — the fiber circle, the spatial slice, and the causal clock — and a discrete symmetry is antiunitary exactly when it contains T (T-P5-1). The total reversal CPT is the one reflection no real world can detect, so the CPT theorem becomes orientation bookkeeping (T-P5-2), while the individual mirrors are free to break because the bulk-to-boundary descent is itself oriented — parity falls on the descent orientation. On the matter side, the paper routes the cosmic matter excess through the flavored chain — fed by GG-A9-SM's ledger phases and delivered to GG-A10-Cosmos's η_B chain — with the sign carried by the Majorana parity $\alpha_{31} = \pi$; that throughput is derived-conditional on its named finite-temperature hypothesis. The same paper consolidates the four-endowment definition of time: time orders (the cone), repeats (the Killing clock), opens one way (the dictionary's irreversibility), and opens the half-plane of lawful analytic continuation (the one-sided spectrum).

GG-P6-Proton — the guarded proton (Arisaka, 2026, P6-Proton). The fourth member of the Predictions Branch, sister to GG-P3-Electron: where that paper runs the ground-state template for the electron, this one runs it for the proton. Nearly everything ever weighed is protons and neutrons, and nearly all of that weight is interaction energy; yet the proton presents one exact mass with zero width, a charge equal and opposite to the electron's to twenty-one decimal places, and a spin of one half its own constituents fail to add up to. It has never once been seen to decay, though the grand unified theories insisted it must. The answer offered is that the proton is the ground attractor (GGA) of the baryonic stratum, and that its baryon number is not a bookkeeping label but a winding of the compact geometry — written by the same twist that breaks the unified gauge symmetry and splits the Higgs multiplet — so that stability is a theorem of the geometry rather than an accident of what has not yet been observed. Eleven questions are read as faces of that one fact, every import at its proved grade and every kill criterion stated. A single verified proton decay falsifies it.

GG-W1-Symmetry — conservation without symmetry (Arisaka, 2026, W1-Symmetry). The first of the two white papers, and the *diachronic* one. Physicists have long believed that things are conserved because the world is symmetric; this review follows that belief through the seven results that built it, in the order they were found, and each gives way. Noether's first theorem ties a conserved quantity to a symmetry that constrains motion; her second, in the same 1918 paper, shows that a symmetry holding independently at every point delivers no conserved quantity — only an identity — so gauge invariance is a redundancy in our description, not a feature of nature. The Bianchi identity conserves magnetic flux for no dynamical reason: a curvature is a curvature. Quantized, the identity can fail at last, and only by a whole number; Green–Schwarz then lets two failures pay for each other, and Hopkins–Singer arrives where the conserved thing is an integer, safe because integers have nowhere to move. The sequence has a direction — conservation laws grow harder to break as they say less about motion — and the program is placed at the end of that arc, at declared grades. Its capstone is the determinism triad: symmetry breaking re-read as symmetry *reading*. It derives nothing new.

GG-W2-Holonomy — the sixteen open problems (Arisaka, 2026, W2-Holonomy). The second white paper, and the *synchronic* one. Physics keeps a short list of questions its own tools cannot close — what happens when a measurement happens, where the Standard Model's unexplained numbers come from, what became of the information that fell into a black hole — median age seventy years. It takes sixteen of them and follows one exact, elementary statement to all sixteen. In the six-dimensional geometry, every point of ordinary space carries two further directions of opposite kind: a closed circle and an open interval. A holonomy — the record a loop keeps of what happened around it — requires closed loops, and an interval has none. Everything on the circle is therefore holonomy: quantized, protected, reversible, a group. Nothing on the interval can be: its transport runs forward only, and each step is final. The circle remembers; the interval forgets. Read with the cohort's open-system chain, that sentence sorts all sixteen: a measurement is the interval writing what the circle carried; the black hole's information was never lost, only billed to the wrong book. Like its sibling it derives nothing new, and it closes with the named measurements on which six of the sixteen die outright.

The cohort inheritance map. Figure 3 shows which Principal Theorem each node carries and which axiom or postulate drives each edge: a spine from GG-A1-Constitution down to GG-A11-Origin, the phenomenology in two framed rows below it, and two flanking columns of two doing opposite jobs — the Foundations Branch feeds the spine, the White-Paper Branch reads it.

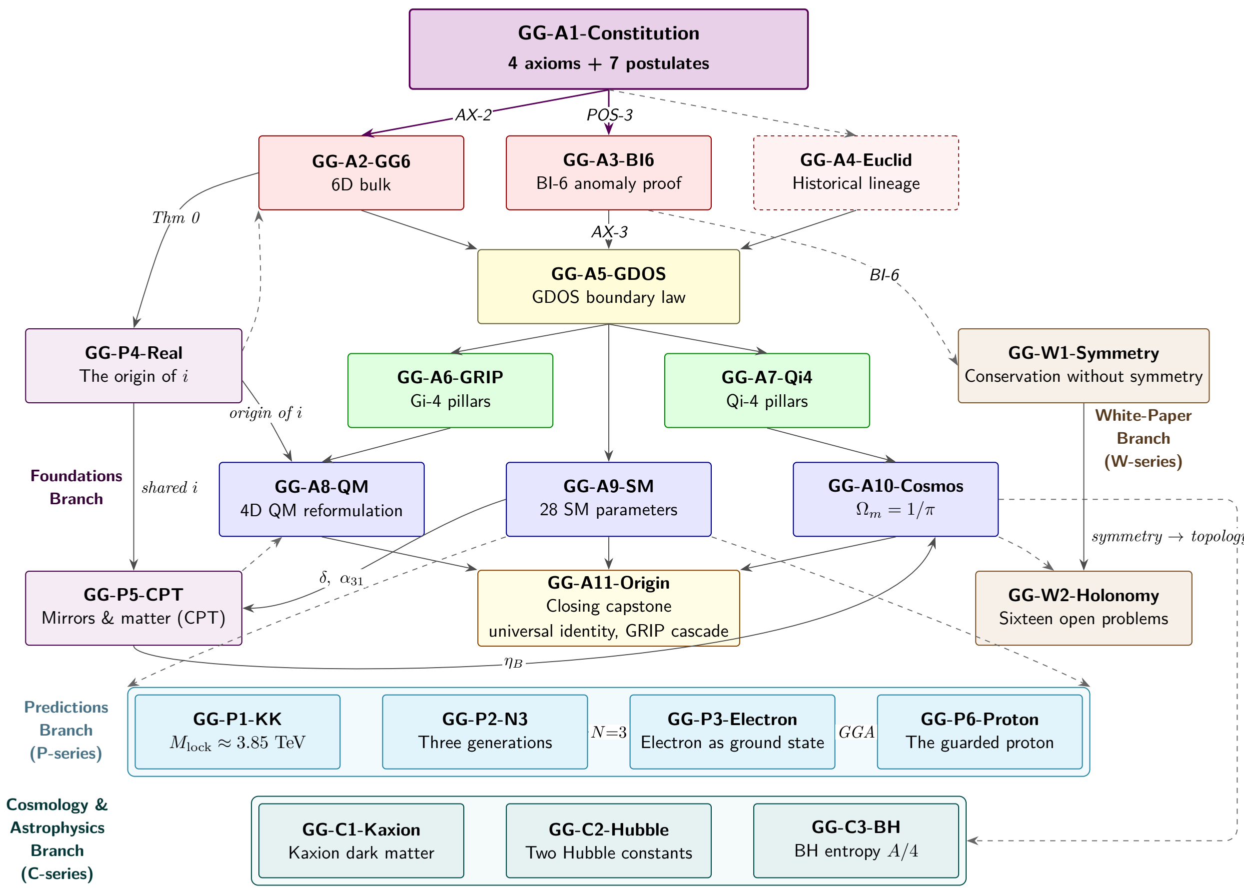

Figure 3: The twenty-two-paper cohort map of GG-Theory. The constitutional root GG-A1-Constitution (violet, top) supplies the four axioms and seven postulates from which the rest of the cohort descends: the GG6 Trio (GG-A2-GG6, GG-A3-BI6, GG-A4-Euclid, red) realizes the bulk geometry; GG-A5-GDOS (yellow) the boundary law; the GDOS Trio pillars (GG-A6-GRIP, GG-A7-Qi4, green) the geometric and quantum-information runtime; the 4D-Physics Trio (GG-A8-QM, GG-A9-SM, GG-A10-Cosmos, blue) the textbook readouts; and the closing capstone GG-A11-Origin (gold) the quarks-to-consciousness identity cascade. Two framed branches carry the phenomenology — the **Predictions Branch** (cyan), whose four papers hand their results along the row by the internal arrows (GG-P2-N3's N=3 into GG-P3-Electron, and that paper's ground-attractor method, GGA, on into GG-P6-Proton), and the **Cosmology & Astrophysics Branch** (teal). The spine is flanked by two columns of two, which do opposite jobs. On the left the **Foundations Branch** (violet) feeds it: GG-P4-Real, fed by GG-A2-GG6's Theorem 0 arena, manufactures the i that GG-A8-QM consumes, and GG-P5-CPT is the GG-A9-SM–GG-A10-Cosmos interface, fed by the ledger phases and feeding the η_B chain across the width of the map, with the shared-i edge descending solid between them. On the right the **White-Paper Branch** (brown) reads it: GG-W1-Symmetry walks the century from Noether to Hopkins–Singer, and GG-W2-Holonomy dissects the structure that arc arrives at — protection by topology rather than by symmetry — across sixteen open problems. The white papers derive nothing new, carrying every result at its parent's declared grade; the single dashed feed drawn into each names its heaviest source, not its only one. *Reading conventions:* solid arrows mark axiom-forced descent and carry an edge label naming the driving axiom or postulate where most illustrative; dashed arrows mark the deployment of derived results, or historical links inherited without being constitutionally forced.

3.2 Roadmap of the ten Parts

The remainder of this paper is organized into nine further Parts, in the canonical constitutional-spine architecture. The visual panorama is **Figure 4**; the prose walkthrough below names each Part in turn.

Part II states the four axioms in a fixed internal format (constitutional statement, mathematical kernel, forced consequences, worked example, Physics-Intuition Remark, relation to the companion papers, historical background). Part III states the seven postulates as ordered admissibility filters in the same seven-block format, with each postulate's historical-background block presented as twelve to fourteen numbered chronological paragraphs that trace the postulate from its earliest historical anchor through to the contemporary mathematical formulation, and closing with an explicit *axiomatic move* paragraph that names the corresponding Stratum of Part V's constitutional-axiom classification. Part IV is the axiomatic handoff: a comprehensive inventory of all the GG-Theory papers, a relations figure that shows their dependency structure, bridge subsections to each companion paper, and the cross-paper coherence map that pins each Principal Theorem Tk to the canonical theorem location in the companion paper where its proof actually lives. No theorems are stated, sketched, or proved inside the present paper; the constitution names the descent chain at high level only and points the reader downstream.

Part V stands a level above the cohort: it observes that the same four constitutional axioms, when applied with different subsets active, are the source of essentially every major theoretical-physics framework of the twentieth century. General relativity, gauge theory, string theory, and AdS/CFT live at the AX-1 + AX-2 level; quantum mechanics lives at AX-1 + AX-2 + AX-3; the Standard Model with ΛCDM lives at AX-1+AX-2+AX-3+AX-4. Each historical framework is, structurally, what the GG-Constitution looks like when a particular subset of its four axioms is operative; its strengths and limitations follow directly from which axioms it uses and which it lacks. A master ledger table and a landscape flowchart make the classification visible at a glance. Part V is highlighted in **Figure 4** because, as Part III of the cohort companion GG-A8-QM is the central operational mechanism of that paper, Part V of the present paper is the central structural payoff of the constitution itself.

Part VI opens the discussion: we position the GG-Constitution against the leading frameworks of twentieth-century physics (the Standard Model, string theory, loop quantum gravity, causal-set theory, axiomatic QFT, and the open-systems formalism) and against the historical chain of partial constitutions sketched above; the six families of adversarial reading that Part IX then answers in full (particle theorist, gravity researcher, quantum-foundations specialist, mathematical physicist, philosopher, and string theorist) and answer each with the relevant constitutional clause; and we close Part VI with a Problems-Solved catalog $\mathrm{P}_1, \ldots, \mathrm{P}_{12}$ that records the twelve foundations-of-physics questions which the twenty-two-paper cohort has now closed, each with the named companion paper and the live experimental falsifier still in play. Part VII states the conclusions. Part VIII gathers the technical appendices: abbreviations, glossary, worked mathematical elaborations *from* each axiom and from each postulate (not derivations *of* axioms, which are foundational by definition), and worked-example templates. The common objections and responses form Part IX; Part X is the inline bibliography with its Relevance paragraphs.

Parts II and III are the axiomatic core; Part IV is the interface to the rest of the GG-Theory program; Part V is the constitutional-axiom classification of the twentieth century; Part VI is the discussion (Problems Solved P_1–P_{12} included), Part VII the conclusions, and Part VIII the technical appendices, Part IX the common objections and responses, and Part X the references. Read in order, the ten Parts compose into a single coherent axiomatic document that any reader can audit clause by clause.

What the present paper establishes vs. what it names. Let us be honest with the reader about the boundary between what this paper will and will not deliver. The present paper *establishes*, with full mathematical statement, the four axioms (Part II) and the seven postulates (Part III); the admissibility predicate Admissible(T) that any candidate theory must satisfy; the immediate inter-clause consistency relations among the eleven clauses; the worked examples that show what each clause forbids and what canonical machinery it sets up (an Aspect 1982 Bell test for AX-1 LC, an Aharonov-Bohm + Berry phase calculation for AX-2 GGEP, a Stern-Gerlach + Stinespring dilation for AX-3 OGGEP, a 28-parameter audit of the Standard Model for AX-4 MSMF, and an analogous worked example for each postulate); and the cross-paper coherence map of where every Principal Theorem T1–T11 is proved. The present paper *names but does not prove* the eleven Principal Theorems themselves. The proofs live in the companion papers, with each proof location pinned to a single canonical line of Table 6 (see Part IV, §27.10). This division of labor — the constitution states the rules and the worked examples, the companion papers carry the theorems — is exactly what the constitutional architecture is for: the constitution is short enough to audit in a single sitting, while the technical machinery that follows from it is delivered in self-contained companion preprints. The worked examples in Parts II and III are not sketch proofs of Tk; they are demonstrations that each axiom and each postulate has mathematical teeth and makes definite predictions *at the level of the clause itself.*

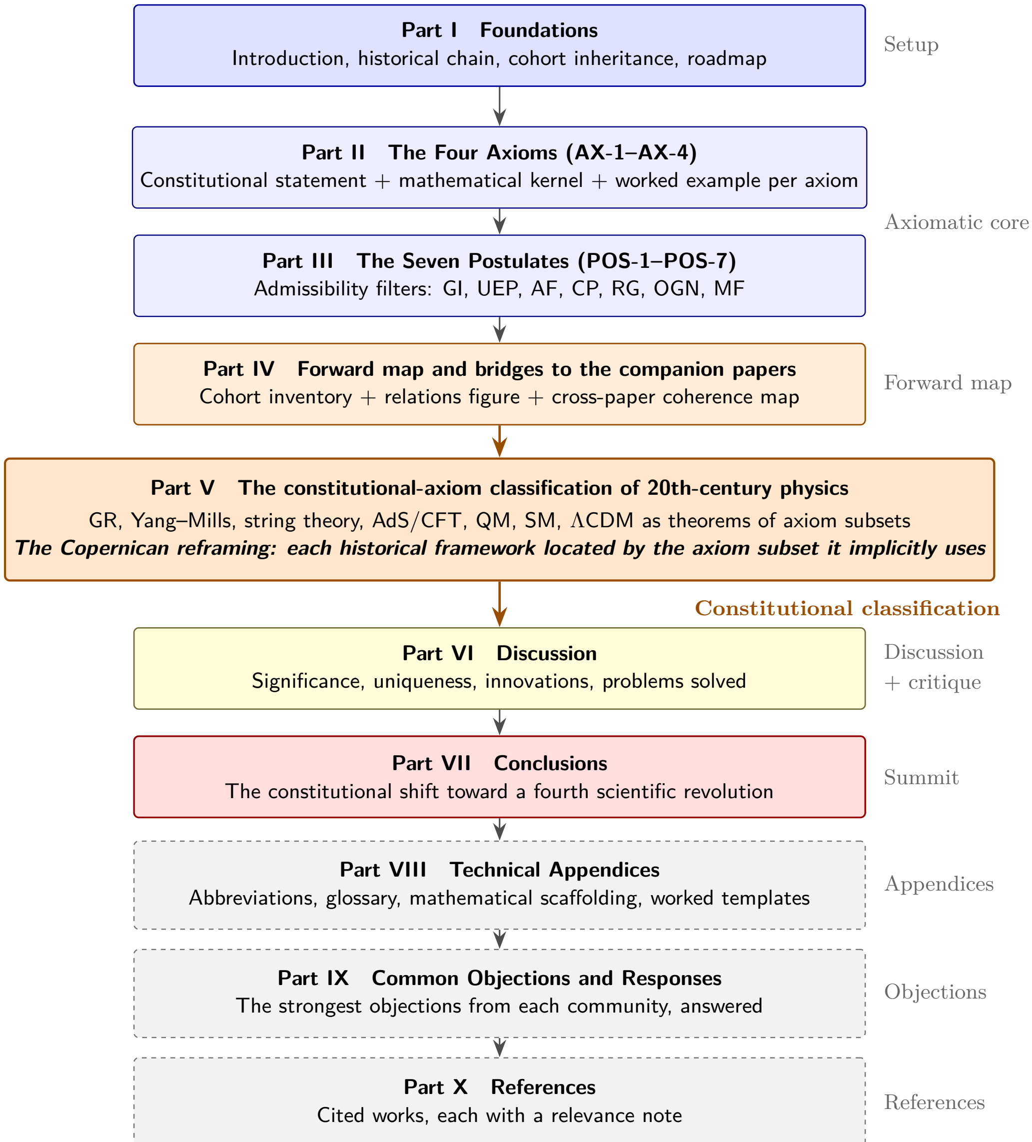

Figure 4: Roadmap of the ten Parts of GG-A1-Constitution. The argument develops in phases. *Setup* (Part I) lays out the constitutional question, the historical chain from Euclid to the open-systems generation, and the twenty-two-paper cohort the constitution compiles. The *axiomatic core* (Parts II–III) states the four axioms AX-1–AX-4 and the seven postulates POS-1–POS-7, each with its mathematical kernel and a worked example. The *forward map* (Part IV) pins every Principal Theorem to the companion paper where its proof lives. The *constitutional-axiom classification* (**Part V**, highlighted) is the Copernican reframing in which general relativity, Yang–Mills theory, string theory, AdS/CFT, quantum mechanics, the Standard Model, and ΛCDM are each located as theorems of a particular subset of the four axioms. Part VI discusses significance, uniqueness, and the ten structural innovations; Part VII states the conclusions; and the three back-matter Parts collect the technical appendices (Part VIII), the common objections and responses (Part IX), and the annotated references (Part X). Part V is highlighted because it is the central structural payoff of the constitution.

Table 1: Motivation map. Structural gaps motivating a new constitution and the corresponding axiom/postulate responses proposed by GG-Theory. This table is used as an audit checklist that links each motivation to a specific clause whose mathematical kernel is spelled out later.

Structural gap	Representative symptom	Constitutional response (preview)
Geometry vs. quantum	No consensus UV completion; gravity treated separately from gauge QFT	GGEP: geometry–gauge composite object; GG-6 engine (Sec. 27)
Measurement/open systems	Unitary evolution + ad hoc collapse; observer cut; environment treated as afterthought	OGGEP: bulk→boundary operational dictionary; POS-CP and POS-MF enforce admissible open dynamics
Hidden dials / parameter freedom	Many fitted constants; scheme/basis dependence mimics tunability	MSMF + OGN: maximize symmetry; fix normalizations by discrete data (Secs. 4–13)
Scale dependence	Different effective theories at different resolutions	POS-RG: coarse-graining commutes with operational semantics; predictions stable under resolution changes

Closing remarks on Part I

Table 1 collects this Part in one place: each row names a structural gap in the present foundations of physics and the clause proposed in answer to it. Use it as an audit checklist. A reader who rejects a clause in Part II or Part III can come back here and see exactly which gap that clause was introduced to close.

Step back from the history for a moment and notice what it actually shows. At every stage, the advance was not a new fact about nature but a new agreement about what a fact is allowed to look like. Euclid did not discover a triangle; he discovered that you could say in advance what you were assuming. Newton did not discover that things fall; he proposed that the falling and the orbiting obey one law, and accepted that this could be checked. Einstein did not discover that light is fast; he took the constancy of its speed as a rule and followed the consequences wherever they led, including to places that offended common sense. The pattern repeats: somebody writes down a constraint, and physics gets smaller and stronger at the same time.

That is what we are proposing to do again, and we should be honest about the cost. An unwritten rulebook cannot be wrong. It bends quietly around each new result, and nobody has to admit anything. The moment you write the rules down, they become attackable — and every place where the written version fails to match what physicists actually do becomes a visible defect rather than an invisible habit. This is uncomfortable, and it is precisely the reason to do it. A discipline that will not state its commitments cannot be corrected in them.

There is a further reason, less about physics and more about who gets to do it. Craft knowledge is transmitted by proximity. It reaches the students of the right supervisors, in the right departments, in the right countries, and it reaches almost nobody else. A rule written on a page reaches a chemist, a biologist, a graduate student far from any famous group, and anyone willing to read carefully and argue back. Whether or not the particular eleven clauses proposed here survive, the practice of writing them down is worth more than any one of them.

We now state the constitution itself. Part II begins with the four axioms — AX-1 LC, AX-2 GGEP, AX-3 OGGEP, AX-4 MSMF — in the rigorous form that every later theorem will cite by name.

Nothing after this point asks the reader to accept anything on authority; every clause is stated so that it can be refused.

Part II

The Four Axioms

LC, GGEP, OGGEP, MSMF

The Semantic Primitives of GG-Theory

An axiom, in this paper, is not a claim that something is true. It is a declaration about what *kind of thing* a physical theory is allowed to be. That distinction matters, and it is worth a moment. When a chemist says a reaction conserves mass, that is a claim about the world. When a chemist says that any acceptable reaction equation must balance, that is a rule about what counts as an equation at all. The four statements in this Part are of the second kind.

There are four of them, and each can be said in a sentence before it is said in mathematics.

AX-1 LC says that causes come before effects and that nothing outruns light. This is the oldest rule in modern physics and the one nobody is willing to give up.

AX-2 GGEP says that the geometry of spacetime and the gauge fields of the forces are not two different kinds of thing that happen to coexist. They are one object, looked at from two angles. Einstein already made gravity into geometry; this axiom finishes the sentence.

AX-3 OGGEP says that observation is not a special act performed by a conscious being. It is a projection: a system with more degrees of freedom is being read by an instrument with fewer. Anything you can actually measure is what survives that projection. This is the axiom that does the most work in this paper, and it is the reason quantum measurement, thermodynamic irreversibility, and black-hole entropy end up in the same chapter.

AX-4 MSMF says that a theory may not carry a dial unless something forces the dial to be there. A soap film stretched across a wire loop does not choose its shape; the constraints choose it. This axiom asks physics to be a soap film.

Each axiom is then presented in the same fixed format: the rigorous statement, the minimum mathematics it needs, the consequences it forces immediately, a plain-language paragraph on what it is really saying, and its relation to the six-dimensional bulk and the boundary law of the companion papers. The historical work each axiom positions itself against is gathered separately, in the century-old history that closes this Part. Readers who want the argument and not the machinery can read the rigorous statement and the plain-language paragraph in each of the four and skip the rest without losing the thread.

4 Overview of the four axioms

Each axiom in this Part is presented in a fixed seven-block internal format that the reader will see repeated four times: a rigorous axiomatic statement; the minimal mathematical kernel that the axiom talks about; the first nontrivial forced consequences; a worked example drawn from a laboratory protocol that any practicing physicist will recognize; a Physics-Intuition Remark in plain language; and the relation to the companion engines GG-6 and GDOS. The predecessors each axiom positions itself against are named not here but in §12, which gathers the four historical lineages into one continuous account. Read together, the four axioms compose into the semantic-primitive layer of the GG-Constitution: AX-1 fixes the causal arrow, AX-2 defines the bulk primitive, AX-3 defines what it means to observe that primitive from the boundary, and AX-4 closes the theory space by forbidding non-forced freedom.

Throughout this Part we adopt a *bulk-to-boundary* staging, and we state the axioms abstractly — they do not presuppose any specific microscopic model. In particular, the dimension of the bulk, the specific bulk metric, and the specific structure group of the principal bundle are not axiomatic inputs at all; they belong to the cohort realization developed in the companion papers (the six-dimensional bulk in GG-A2-GG6 (Arisaka, 2026, A2-GG6), the modified Bianchi closure in GG-A3-BI6 (Arisaka, 2026, A3-BI6), and the integer ledger in GG-A4-Euclid (Arisaka, 2026, A4-Euclid)), and are theorems of the axioms plus the seven postulates plus the cohort's choice of admissible bulk. Indeed, the value of writing the axioms abstractly is exactly that any candidate theory — not only the GG-Theory one — can be audited against them clause by clause.

4.1 Common mathematical arena for the axioms

Let us first investigate the common mathematical arena that all four axioms talk about. Before any axiom can be stated rigorously, we must fix the bulk geometry, the composite connection, and the boundary operational package — the three ingredients that will appear in every later constitutional clause.

(i) Bulk geometry. Let $(\mathcal{M}, g)$ be a smooth, time-oriented Lorentzian manifold of admissible dimension, with metric g encoding the causal structure via its light cone. No further specification of $(\mathcal{M}, g)$ is required for the four axioms to be stated; in particular, the dimension of $\mathcal{M}$, the explicit form of g, and any compact direction structure belong to the cohort realization rather than to the axioms. The concrete six-dimensional bulk that the cohort framework adopts as its canonical realization is constructed in GG-A2-GG6 (Arisaka, 2026, A2-GG6), where the dimension six, the scale-profile metric, and the integer ledger lock-length $K = 35$ are derived as theorems of AX-2 GGEP together with AX-4 MSMF and the postulate stack. The reader who wishes to follow the worked examples of the present paper on the concrete cohort bulk should consult GG-A2-GG6 for the explicit form; the axiomatic content here does not require it. Throughout the cohort, this 6D bulk is read on the field-theory side of the bulk–boundary correspondence: its fifth (scale) direction is the renormalization-group axis $r = \ln(E_{\mathrm{GUT}}/\mu)$, not a Randall–Sundrum spatial dimension; the radial direction denotes RG running rather than a gravitational extension of an extra spatial direction, and the explicit renormalization-group construction is given in GG-A2-GG6 (Arisaka, 2026, A2-GG6).

(ii) Composite connection. Let $P \to \mathcal{M}$ be a principal bundle with structure group G. The four axioms below are stated for any admissible such bundle; they do not name a specific structure group, and they do not require any particular factorization of G. The concrete four-factor structure group of the cohort realization $(\mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi})$ is derived as a theorem of AX-2 GGEP together with AX-4 MSMF and POS-3 AF in the cohort companion GG-A2-GG6 (Arisaka, 2026, A2-GG6); that derivation is not repeated here. A *composite (locked) connection* is a Lie-algebra valued one-form on P,

$$\mathcal{A} \;=\; \omega[g] \;\oplus\; A^{\text{gauge}}, \tag{3}$$

where $\omega[g]$ is the spin connection induced by the bulk metric and A^{gauge} collects the internal gauge connections. The corresponding curvature is

$$\mathcal{F} \;=\; d\mathcal{A} + \mathcal{A} \wedge \mathcal{A} \;=\; R[\omega] \;\oplus\; F[A^{\text{gauge}}], \tag{4}$$

and the covariant derivative acting on a field Ψ in an associated bundle is

$$\nabla_A^{(\mathcal{A})}\Psi \;=\; \partial_A \Psi + \mathcal{A}_A \cdot \Psi. \tag{5}$$

(iii) Boundary operational package. Let the boundary be $\partial\mathcal{M}$ (an operational screen/sector supporting registered records). In the cohort realization of GG-A2-GG6 (Arisaka, 2026, A2-GG6), the boundary is specifically $\mathcal{M}_4 = \partial\mathcal{M}_6$ at the $r = 0$ end of the radial direction; the axiomatic content here does not presuppose this specific dimensionality. Operationally, the boundary is described by: (i) a state space (classical distributions or quantum density operators ρ on a Hilbert space $\mathcal{H}$), (ii) a set of registered observables (POVMs or instruments), and (iii) admissible time evolution between interventions (channels $\Phi_{t,s}$). The OGGEP axiom will legislate that these are *outputs* of a bulk→boundary map rather than optional add-ons.

We now proceed axiom by axiom.

5 AX-1: LC (Locality and Causality)

5.1 Constitutional statement (rigorous)

Axiom 1 (AX-1 (LC): Locality and Causality)**.** *For every admissible bulk configuration and every admissible boundary intervention protocol, the induced boundary evolution is* local *(generated by local/quasilocal structures) and* causal*: registered boundary records at time t depend only on boundary-accessible data in the causal past of t. Equivalently, the operational influence of any intervention vanishes outside the future light cone defined by the bulk/boundary causal structure, and no admissible effective description contains acausal (advanced) response kernels.*

Three clarifications are constitutional (not interpretational):

1. **LC is about operational influence, not about metaphysical "hidden variables."** The axiom is enforced at the level of registered statistics and admissible effective kernels.

2. **LC is formulated for open systems.** Because OGGEP defines observation as an open-system projection, LC must hold for open evolution maps and measurement instruments, not only for closed unitary dynamics.

3. **LC entails point-like locality: the fundamental excitations are local field quanta, not extended objects.** Microcausality (8) attaches observables to *points* x of the manifold and requires them to commute at spacelike separation; the admissible excitations are therefore point-like quanta of local fields. LC thereby excludes fundamental *extended* objects — strings or branes — whose constituents are not localized at a point and whose microcausality is not pointwise. GG-6 is in this precise sense a point-particle framework, and it remains one even while geometrizing the gauge interaction, because its two further dimensions are non-spatial (a scale and a gauge dimension, developed under POS-5 and POS-6; see (Arisaka, 2026, A2-GG6), and (Arisaka, 2026, A4-Euclid) for the philosophical reading).

5.2 Mathematical kernel

LC can be encoded in several equivalent mathematical statements, depending on the level of description.

(i) Retarded support of Green's functions (field level). Consider a linear hyperbolic equation on the boundary (or projected from the bulk),

$$\mathcal{L}\phi(x) = J(x), \tag{6}$$

for a differential operator $\mathcal{L}$. LC requires that the physical propagator be the *retarded* Green's function G_R:

$$\phi(x) = \int d^4y\, G_R(x,y)\, J(y), \qquad G_R(x,y) = 0 \text{ if } x \notin J^+(y), \tag{7}$$

where $J^+(y)$ is the causal future of y.

(ii) Microcausality (operator level). In a relativistic QFT regime, locality and causality are encoded by microcausality: for local observables $\hat{\mathcal{O}}(x)$ and $\hat{\mathcal{O}}(y)$,

$$[\hat{\mathcal{O}}(x), \hat{\mathcal{O}}(y)] = 0 \qquad \text{if } (x-y)^2 < 0, \tag{8}$$

a condition consistent with special relativity (Einstein, 1905, Minkowski, 1908) and standard QFT axioms.

(iii) Retarded kernels for open evolution (channel level). Let $\rho(t)$ be a boundary state (density operator or probability distribution). A general causal effective evolution may be written using a memory kernel:

$$\frac{d}{dt}\rho(t) = \int_{-\infty}^{+\infty} dt'\, \mathcal{K}(t,t')\, \rho(t'), \qquad \mathcal{K}(t,t') = 0 \ \text{ for } t' > t, \tag{9}$$

where $\mathcal{K}$ is a superoperator kernel. LC is precisely the statement that $\mathcal{K}$ has retarded support.

In the Markovian limit (no memory beyond $\rho(t)$) LC is consistent with a forward-time semigroup of maps

$$\rho(t) = \Phi_{t,t_0}(\rho(t_0)), \qquad \Phi_{t_2,t_0} = \Phi_{t_2,t_1} \circ \Phi_{t_1,t_0} \quad (t_2 \geq t_1 \geq t_0), \tag{10}$$

with $\Phi_{t,t}$ the identity channel. If the dynamics is time-homogeneous, $\Phi_{t,t_0} \equiv \Phi_{t-t_0}$ and

$$\Phi_{t+s} = \Phi_t \circ \Phi_s, \qquad \Phi_0 = \mathrm{id}, \qquad t, s \geq 0. \tag{11}$$

This is the operational form of an "arrow of time" for open systems.

5.3 Forced consequences / derivations

Derivation 1 (LC ⇒ forward semigroup for memoryless evolution). Assume: (i) the effective description has no memory beyond $\rho(t)$ and (ii) interventions are localized in time. Then the state at t_2 depends only on the state at t_1 and the evolution between them, implying (10). Time-homogeneity reduces this to the semigroup law (11). The restriction $t \geq 0$ (no inverse map in general) is not a technicality: it is the operational content of irreversibility once records are created.

Derivation 2 (LC + locality ⇒ no superluminal signaling). In any operational theory whose statistics are computed from local algebras satisfying microcausality (8), interventions in a spacelike-separated region commute with observables in the target region. Hence the target region's marginal statistics cannot depend on spacelike-separated choices, blocking superluminal signaling at the level of registered records. (Foundationally, this is distinct from Bell's notion of "local causality" for hidden variables (Bell, 1964), but it is the relevant notion for an axiomatic operational constitution.)

Derivation 3 (LC as a necessary precondition for OGGEP). Because OGGEP will define measurement as a bulk→boundary projection producing irreversible records, LC must already constrain the admissible operational map: the map cannot output channels/instruments that enable advanced response or backward-in-time dependence. Thus AX-1 is logically prior to AX-3.

5.4 Further mathematical elaboration: microcausality, no-signaling, and causality ⇒ analyticity

Before turning to frequency-domain analyticity, we collect the two standard-textbook formulations of AX-1 LC that the constitution inherits and elevates. *In relativistic QFT*, locality is encoded as *microcausality*: for local Heisenberg operators $\mathcal{O}(x)$ and $\mathcal{O}'(y)$,

$$[\mathcal{O}(x), \mathcal{O}'(y)]_{\mp} = 0, \qquad (x-y)^2 < 0, \tag{12}$$

where $[\cdot,\cdot]_{\mp}$ is a commutator/anticommutator for bosons/fermions and $(x-y)^2 < 0$ denotes spacelike separation (Haag, 1992, Streater & Wightman, 1964). A complementary expression uses retarded Green functions: for a relativistic field ϕ with source J obeying $(\Box + m^2)\phi = J$, the response $\phi(x) = \int d^4y\, G_{\mathrm{ret}}(x-y)\, J(y)$ respects causality via $G_{\mathrm{ret}}(x-y) = 0$ for $x^0 < y^0$. In interacting QFT the two formulations agree: commutators vanish outside the light cone.

On the operational boundary, AX-1 LC takes the form of *no-signaling*. For a bipartite system AB with state ρ_{AB}, a CPTP map Φ_A acting locally on A cannot change the reduced state on B:

$$\mathrm{Tr}_A[(\Phi_A \otimes \mathrm{id}_B)(\rho_{AB})] = \mathrm{Tr}_A(\rho_{AB}). \tag{13}$$

Equation (13) follows directly from trace preservation and is the operational, quantum-information-language expression of locality (Kraus, 1971, Nielsen & Chuang, 2010, Stinespring, 1955). Indeed, AX-1 LC is the constitutional commitment that Eqs. (12) and (13) are not theorem-level results to be checked case by case but admissibility filters that every candidate operational kernel must respect from the outset.

Terminology note. Some authors use "local causality" in the Bell sense — the demand that the joint statistics of spacelike-separated experiments factorize over local hidden variables — a demand which Bell-test experiments (Aspect, Dalibard, & Roger, 1982, Giustina et al., 2015, Hensen et al., 2015) have empirically refuted. The constitutional AX-1 LC used in this paper is *not* the Bell-style local-causality demand; it is the weaker and operationally adequate combination of microcausality (Eq. (12)) and no-signaling (Eq. (13)), both of which are compatible with — and indeed verified by — the loophole-free Bell-test data.

Beyond literal light-cone tomography, AX-1 is tested experimentally by frequency-domain constraints. If a linear response function $\chi(t)$ is causal (retarded), $\chi(t) = 0$ for $t < 0$, then its Fourier transform

$$\chi(\omega) = \int_{-\infty}^{+\infty} \mathrm{d}t\, \mathrm{e}^{+\mathrm{i}\omega t}\chi(t) = \int_{0}^{+\infty} \mathrm{d}t\, \mathrm{e}^{+\mathrm{i}\omega t}\chi(t) \tag{14}$$

extends analytically to the upper-half complex ω plane (a Paley–Wiener type consequence of support on $t \geq 0$). Analyticity implies *dispersion relations* (Kramers–Kronig):

$$\Re\chi(\omega) = \frac{1}{\pi}\,\mathrm{P}\!\int_{-\infty}^{+\infty} \mathrm{d}\omega'\, \frac{\Im\chi(\omega')}{\omega' - \omega}, \tag{15}$$

$$\Im\chi(\omega) = -\frac{1}{\pi}\,\mathrm{P}\!\int_{-\infty}^{+\infty} \mathrm{d}\omega'\, \frac{\Re\chi(\omega')}{\omega' - \omega}, \tag{16}$$

where P denotes the principal value. Thus, any proposed effective kernel that violates these relations (after accounting for instrument response and coarse-graining) signals an *acausal* or *non-admissible* operational model.

In open systems the same logic applies to transfer functions of estimators. If $x(t)$ is a registered record produced by a linear filter $h(t)$ acting on an input $u(t)$,

$$x(t) = \int \mathrm{d}t'\, h(t - t')\, u(t') + \eta(t), \tag{17}$$

then LC demands $h(t < 0) = 0$, and the same analyticity constraints follow for $H(\omega)$. This provides an experimentally accessible "LC audit" that is independent of microscopic interpretation: causality is enforced at the level of *registered records* and their admissible kernels.

5.5 Worked example: the Aspect 1982 time-varying-analyzer Bell test

Let us picture this concretely. The cleanest laboratory falsification target for AX-1 LC is the Bell-test family of experiments, beginning with the time-varying-analyzer version of Aspect, Dalibard, & Roger (1982) and continuing through the loophole-free realizations of Giustina et al. (2015), Hensen et al. (2015). The experiment runs as follows. A pair of polarization-entangled photons in the singlet state

$$|\Psi^-\rangle = \tfrac{1}{\sqrt{2}}\big(|H\rangle_A|V\rangle_B - |V\rangle_A|H\rangle_B\big) \tag{18}$$

is sent to two spatially separated stations A and B, each carrying a polarizer whose orientation α_A or α_B is chosen by a fast random number generator while the photons are already in flight. Each station registers a binary outcome $a, b \in \{+1, -1\}$. Quantum mechanics predicts the correlation $\langle ab\rangle = -\cos(2(\alpha_A - \alpha_B))$, which violates the CHSH bound $|S| \le 2$ (Clauser et al., 1969) on the α-averaged combination $S = E(\alpha,\beta) - E(\alpha,\beta') + E(\alpha',\beta) + E(\alpha',\beta')$ by reaching $|S| = 2\sqrt{2}$. The Aspect experiment registered $|S| \approx 2.70$, and the loophole-free experiments of 2015 verified this violation while closing the locality and detection loopholes simultaneously.

What does AX-1 LC require of the registered records, and how do these experiments confirm it? Two operational predictions are forced. *First*, the *marginal* statistics at station A must be independent of the polarizer setting at station B (*no-signaling*): for any choice of α_B, $\sum_b P(a, b \mid \alpha_A, \alpha_B) = P(a \mid \alpha_A)$. *Second*, the joint correlation can be non-classical (i.e. violate the CHSH bound) while still respecting the causal-arrow constraint that interventions in the future light cone of one station do not influence the marginal record at the other station. Both predictions were confirmed to high statistical significance in the Aspect experiment and re-confirmed under loophole-free conditions in 2015.

The axiomatic reading is exactly this: AX-1 LC is not the metaphysical claim that the universe is locally causal in the sense of Bell's hidden-variable theorem. It is the operational claim that registered records respect the light-cone structure of the bulk-to-boundary projection. The Aspect experiment violates Bell-style local-causality but satisfies operational locality and causality in exactly the sense AX-1 requires. This is a feature of the constitution, not a bug: the GG-Theory program accommodates Bell-violating correlations while still forbidding superluminal signaling, because AX-1 is about record statistics rather than hidden variables.

5.6 Physics intuition

Remark 1 (Physics intuition for AX-1)**.** Roughly speaking, LC says that physics is not allowed to compute today's record using tomorrow's knob setting. In practice, this forbids three families of admissible-looking but actually inadmissible models: advanced propagators presented as physical response; acausal kernels hidden inside effective open-system master equations; and the "interpretational loophole" in which measurement is declared external to the theory and therefore exempt from causal auditing. Once we have agreed that registered records are the operational content of physics, we have already committed to a constitutional ordering of cause and effect.

5.7 Relation to GG-6 and GDOS

- **Relation to GG-6.** GG-6 will be formulated as a bulk geometric engine (AdS-like causal structure). LC restricts admissible bulk geometries and boundary couplings so that the induced boundary response is retarded.
- **Relation to GDOS.** GDOS is the runtime theory of open systems. LC is the reason GDOS is naturally written in forward-time form (semigroups, kernels with retarded support), and it sets the admissibility condition for "ports" (environment couplings) used in system-instance packets.

6 AX-2: GGEP (Geometry–Gauge Equivalence Principle)

6.1 Constitutional statement (rigorous)

Axiom 2 (AX-2 (GGEP): Geometry–Gauge Equivalence Principle)**.** *In a world with gravity and gauge interactions, there exists a* single primitive geometric object*—a composite connection $\mathcal{A}$ on a principal bundle over the bulk—such that:*

1. ***Locked equivalence / local flattening.*** *For any timelike curve γ and any event $p \in \gamma$, there exists a combined choice of (i) local coordinates, (ii) local Lorentz frame, and (iii) internal gauge trivialization, in which the pullback of the composite connection along γ vanishes at p (and can be flattened to first order along γ in the equivalence-principle sense).*
2. ***Invariant physics.*** *All physical content is carried by curvature and holonomy invariants of $\mathcal{A}$ (and by the induced topological data); "forces" appear when working in an unlocked description.*

This upgrades Einstein's equivalence principle from "gravity only" to "geometry+gauge as one locked structure".

The arena these two axioms force. Axioms AX-1 (LC) and AX-2 (GGEP), taken together, do more than constrain a pre-given manifold — they *force the manifold itself.* Locality and causality oblige any interacting, charged quantum theory to carry two structures it cannot be written without (a renormalization scale and a local gauge phase), and geometry–gauge equivalence obliges each to be realized as geometry. The result is that the bulk must be four-dimensional Lorentzian spacetime supplemented by exactly two further coordinates — a non-spatial *scale* dimension and a non-spatial *phase* dimension. This is established rigorously as Theorem 0 (T-GG6-0) of (Arisaka, 2026, A2-GG6); we record it here because it is the joint geometric content of AX-1 and AX-2, and the reason the extra dimensions of GG-6 are derived rather than postulated.

6.2 Mathematical kernel

(i) Composite connection and curvature. The composite connection $\mathcal{A}$ and curvature $\mathcal{F}$ were defined in Eqs. (3)–(4). Local gauge transformations act as

$$\mathcal{A} \mapsto \mathcal{A}' = g^{-1}\mathcal{A}g + g^{-1}dg, \qquad \mathcal{F} \mapsto \mathcal{F}' = g^{-1}\mathcal{F}g, \tag{19}$$

and diffeomorphisms act by pullback on forms. The locked structure is not a new mathematical object; it is the *central claim* that this single object is the correct primitive for unification.

(ii) Holonomy/Wilson loops as invariants. For a curve C in $\mathcal{M}_6$, define the holonomy (Wilson line)

$$U(C) = \mathcal{P}\exp\left(\int_C \mathcal{A}\right), \tag{20}$$

where $\mathcal{P}$ denotes path ordering. For a small loop $\partial\Sigma$ bounding an oriented surface Σ,

$$U(\partial\Sigma) \;=\; \exp\left(\int_\Sigma \mathcal{F}\right) + \mathcal{O}(\Sigma^{3/2}), \tag{21}$$

so curvature is the infinitesimal holonomy.

(iii) Locked chart (first-order flattening). A compact local rendering of the locked condition is: for a timelike curve $\gamma(\tau)$ with tangent $u^A = \dot{x}^A$, there exists a local trivialization such that at a chosen parameter value τ_0,

$$\mathcal{A}_A(\gamma(\tau_0)) = 0, \qquad u^B\partial_B(\mathcal{A}_A u^A)\Big|_{\tau_0} = 0, \tag{22}$$

while $\mathcal{F}(\gamma(\tau_0))$ may be nonzero. Equation (22) is the composite analog of normal coordinates in GR and of local gauge trivialization in Yang–Mills theory.

6.3 Forced consequences / derivations

Derivation 1 (local construction of $\mathcal{A}(p) = 0$). At any point $p \in \mathcal{M}_6$, choose local coordinates centered at p and a group element $g(x)$ with $g(p) = \mathbb{I}$. Because $\mathcal{A}$ is a smooth one-form, one can choose $g(x)$ such that $\partial_A g(p) = -\mathcal{A}_A(p)$. Then the transformed connection (19) satisfies $\mathcal{A}'_A(p) = 0$. This is the standard local trivialization property of connections (Kobayashi & Nomizu, 1963, Nakahara, 2003). GGEP's additional claim is *conceptual uniqueness*: this is the *definition of inertial/force-free structure* in the unified theory.

Derivation 2 (unified geodesic/Lorentz-force form from a worldline action). Consider a point-like probe carrying generalized charges Q in a representation of G_{tot}. A minimal worldline action capturing both geometry and gauge coupling is

$$S[\gamma, Q] = \int d\tau \left[\frac{m}{2}\, g_{AB}(x)\, \dot{x}^A \dot{x}^B + \langle Q(\tau), \mathcal{A}_A(x)\rangle \dot{x}^A\right], \tag{23}$$

where: m is an inertial mass parameter, τ is an affine parameter, $\langle\cdot,\cdot\rangle$ is the natural pairing between charges and connection components, and $\dot{x}^A \equiv dx^A/d\tau$. Varying with respect to x^A yields a generalized geodesic equation, schematically

$$m\,\frac{D\dot{x}^A}{d\tau} = \langle Q, \mathcal{F}^A{}_B\rangle \dot{x}^B, \tag{24}$$

where $D/d\tau$ is the covariant derivative induced by the metric/spin part of the composite connection. In a locked chart at p, $\mathcal{A}(p) = 0$ and inertial motion is locally straight, while curvature provides the first nontrivial invariant content—exactly the equivalence-principle logic.

Derivation 3 (geometrization of discreteness from compact holonomy). If the bulk contains a compact $U(1)$ fiber coordinate $\theta \sim \theta + 2\pi$, then single-valuedness of a wavefunction $\Psi(\theta)$ implies a Fourier expansion

$$\Psi(\theta) = \sum_{n\in\mathbb{Z}} c_n e^{in\theta}, \tag{25}$$

and the generator of translations $-i\partial_\theta$ has integer eigenvalues. Restoring $\hbar$, the momentum spectrum is quantized:

$$p_\theta = n\hbar, \qquad n \in \mathbb{Z}. \tag{26}$$

In Kaluza–Klein language, p_θ appears as a conserved charge in the boundary effective theory. This provides an explicit mechanism for the slogan "geometrize quantum physics": discreteness is a topological/geometric consequence rather than an externally imposed quantization rule (Dirac, 1931, Kobayashi & Nomizu, 1963, Nakahara, 2003). One register sentence harmonizes this display with the arena: the circle itself is the constitutional object — the arena says $\theta \sim \theta + 2\pi$ and nothing more — while $e^{in\theta}$ is its boundary representation, the quarter-turn of the circle being the forced complex structure of T-P4-1 (Arisaka, 2026, P4-Real).

6.4 Further mathematical elaboration: composite connection, covariant derivative, and unified force law

A compact way to express GGEP is that the *covariant derivative* is built from a single composite connection. For a matter field ψ carrying both Lorentz/spin and internal gauge indices, one writes

$$D_\mu\psi = \left(\partial_\mu + \frac{1}{4}\,\omega_\mu^{ab}\gamma_{ab} + \mathrm{i}g\,A_\mu^a T^a\right)\psi \equiv (\partial_\mu + \mathcal{A}_\mu)\,\psi, \tag{27}$$

where ω_μ^{ab} is the spin connection, A_μ^a is a Yang–Mills connection, and $\mathcal{A}_\mu$ denotes the *locked* (composite) connection acting on ψ. Its curvature is likewise composite,

$$\mathcal{F}_{\mu\nu} := [D_\mu, D_\nu] = \frac{1}{4}\,R_{\mu\nu}^{ab}\gamma_{ab} + \mathrm{i}g\,F_{\mu\nu}^a T^a, \tag{28}$$

so that "force" and "curvature" are the same object in representation-dependent dress.

In a point-particle limit, one can view motion as parallel transport in the composite connection. A standard calculation shows that the usual geodesic term and Lorentz-force term arise from extremizing a single worldline functional with composite coupling:

$$S[x] = -m \int \mathrm{d}s \; + \; q \int A_\mu(x)\, \mathrm{d}x^\mu, \tag{29}$$

whose Euler–Lagrange equations yield

$$m\, \frac{Du^\mu}{\mathrm{d}\tau} = q\, F^\mu{}_\nu\, u^\nu, \qquad u^\mu = \frac{\mathrm{d}x^\mu}{\mathrm{d}\tau}. \tag{30}$$

GGEP interprets this familiar "sum" as a *single* statement about parallel transport in $\mathcal{A}$: the separation into "gravity" and "gauge force" is representation bookkeeping rather than a separation of primitives.

Finally, the holonomy viewpoint makes quantization conditions geometric. For a compact $U(1)$ factor, the Wilson loop

$$W(\gamma) = \exp\!\Big(\mathrm{i}q \oint_\gamma A\Big) \tag{31}$$

is invariant under small deformations and, in topologically nontrivial sectors, forces charge/flux quantization. This is the same mathematical discipline behind Dirac quantization (Dirac, 1931) and motivates why OGN (POS-6) will later insist on a canonical integer charge lattice: if holonomy is the invariant content, then basis drift in Abelian normalization is not physics but bookkeeping.

6.5 Worked example: Aharonov–Bohm effect plus Berry phase

The textbook demonstrations that gauge-and-geometry are best treated as *one* object are the Aharonov-Bohm effect (Aharonov & Bohm, 1959) and Berry's geometric phase (Berry, 1984). Both reveal that what we call "physical content" lives in the holonomy of the composite connection, not in the local field strength.

The Aharonov-Bohm setup is as follows. An electron beam is split into two paths that pass on either side of a long solenoid carrying magnetic flux Φ but no field outside the solenoid (the field $\mathbf{B}$ vanishes everywhere the electrons can go). The two paths recombine and produce an interference pattern. Classical electromagnetism predicts no shift, since $\mathbf{B} = 0$ along the electron paths. Yet the fringe pattern *does* shift, by a phase

$$\Delta\varphi \;=\; \frac{q}{\hbar} \oint_C A\, d\ell \;=\; \frac{q\Phi}{\hbar}, \tag{32}$$

where C is the closed loop encircling the solenoid and q is the electron charge. The phase is the Wilson loop of the U(1) gauge connection A around C — the holonomy of the composite connection in our language — and it is physically measurable even though the local field strength $\mathbf{B} = dA$ vanishes everywhere the electron sees. Yet the experimental observation of Eq. (32) in the Tonomura electron-microscope experiments of the mid-1980s is one of the cleanest demonstrations in physics that gauge potentials carry physical content beyond their field strengths.

The Berry-phase example sharpens the geometric reading. When a quantum system $|\psi(\mathbf{R})\rangle$ is adiabatically transported around a closed loop in some external parameter space $\mathbf{R}$, it acquires —

in addition to the dynamical phase $-\int E\,dt/\hbar$ — a geometric phase

$$\gamma_C \;=\; \oint_C \langle\psi(\mathbf{R})|\, i\,\nabla_{\mathbf{R}}\,|\psi(\mathbf{R})\rangle \cdot d\mathbf{R}. \tag{33}$$

The integrand is the Berry connection on the parameter manifold; γ_C is its holonomy. As Berry showed in 1984, γ_C depends only on the geometry of the loop C in parameter space, not on the dynamical history — a fact that is invisible in any treatment that does not promote the connection to a primitive geometric object.

The axiomatic reading is exactly this: AX-2 GGEP declares that physical content lives in the curvature and holonomy invariants of the composite connection $\mathcal{A}$ on the principal G_{tot}-bundle, not in the local components of $\mathcal{A}$ themselves. The Aharonov-Bohm phase and the Berry phase are not exotic curiosities — they are the empirical proof that gauge potentials and geometric phases must be treated as parts of one geometric primitive. In the GG-Theory program, the same logic forces the four-factor composite group $G_{\text{tot}} = \text{Spin}(1,5) \times \text{SU}(5) \times \text{U}(1)_B \times \text{U}(1)_{Qi}$: each factor is the holonomy carrier of one physical sector (Arisaka, 2026, A2-GG6).

6.6 Physics intuition

Remark 2 (Physics intuition for AX-2)**.** Roughly speaking, GGEP says that what we usually call "gauge force" is not a separate ingredient that must be quantized on top of geometry — it is part of geometry from the beginning, very much like the way the electric and magnetic fields became, after Maxwell, two faces of one underlying object. In this view, "free" motion means parallel transport (horizontal lift) with respect to the composite connection, and "force" is the bookkeeping artifact of describing that transport in a non-inertial (unlocked) chart. The quantum signature — the phase that the wave function picks up around a flux line, the discrete charge that survives every gauge change, the Berry phase that any adiabatic loop in parameter space accumulates — is then traced to holonomy and topology, not to a separate quantization rule pasted onto the side of geometry. The unification of gravity and gauge into a single composite connection is the axiomatic move that lets the 6D bulk of GG-6 stand in as the realization of GGEP.

6.7 Relation to GG-6 and GDOS

- **Relation to GG-6.** GG-6 is the concrete realization of GGEP: a six-dimensional bulk in which the composite connection locks gravity with a specific gauge content (minimally $SU(5)\times U(1)_B$) and in which anomaly cancellation fixes otherwise free coefficients (Arisaka, 2026, A2-GG6).
- **Relation to GDOS.** GGEP determines *what* is projected by OGGEP: curvature/holonomy data of the composite connection. GDOS then describes *how* that projected data evolves as an open system on the boundary (Arisaka, 2026, A5-GDOS).

7 AX-3: OGGEP (Operational/Open GGEP)

7.1 Constitutional statement (rigorous)

Axiom 3 (AX-3 (OGGEP): Operational/Open GGEP)**.** *A bulk theory is not physically defined unless it specifies a* fixed operational dictionary *that maps bulk structure to registered boundary observables and admissible open-system evolution. Concretely, there exists a causal, gauge-covariant bulk↔boundary map $\mathcal{D}$ such that for every admissible bulk configuration B,*

$$\mathcal{D}(B) \;=\; \Big(\mathcal{H}, \rho, \{\mathcal{I}_\alpha\}, \{\Phi_{t,s}\}, \dots\Big), \tag{34}$$

where: ρ is a boundary state, $\{\mathcal{I}_\alpha\}$ is a set of measurement instruments *(with POVM semantics), and $\Phi_{t,s}$ are admissible boundary evolution maps between interventions. The map must satisfy: (i) LC/retardedness (AX-1), (ii) compatibility with the gauge/geometry equivalences of GGEP (AX-2), and (iii) operational positivity (channels/instruments map physical states to physical states).*

A register note on the symbol $\mathcal{H}$. The operational dictionary outputs a complex Hilbert space, but the complex scalars of $\mathcal{H}$ are not a constitutional primitive. The bulk clauses of this constitution are stated over the reals throughout; the boundary's imaginary unit is the derived quarter-turn of two real bulk structures — the charge circle and the causal clock — whose forced agreement is the existence of antiparticles (T-P4-1/2/3 of Arisaka, 2026, P4-Real; re-proved as T-P5-A/B/C of Arisaka, 2026, P5-CPT; QM-register development in Arisaka, 2026, A8-QM; constitutional pricing in L-Constitution-1, §8.5, at candidate grade). The constitution therefore uses $\mathcal{H}$ as boundary shorthand, not as bulk input.

This axiom is the axiomatic answer to the century-old ambiguity of "what is a measurement?" In GG-Theory, measurement is not a metaphysical add-on; it is part of the theory's syntax.

7.2 Mathematical kernel

(i) Instruments and POVMs. A measurement with outcomes labeled by α is represented by an *instrument*: a set $\{\mathcal{I}_\alpha\}$ of completely positive maps such that $\sum_\alpha \mathcal{I}_\alpha$ is trace-preserving. A Kraus representation is

$$\mathcal{I}_\alpha(\rho) = \sum_k K_{\alpha k}\,\rho\,K_{\alpha k}^\dagger, \qquad \sum_{\alpha,k} K_{\alpha k}^\dagger K_{\alpha k} = \mathbf{1}. \tag{35}$$

The associated POVM elements are

$$E_\alpha = \sum_k K_{\alpha k}^\dagger K_{\alpha k}, \qquad E_\alpha \succeq 0, \qquad \sum_\alpha E_\alpha = \mathbf{1}. \tag{36}$$

Outcome probabilities and conditional post-measurement states are

$$p_\alpha = \mathrm{Tr}(E_\alpha \rho), \qquad \rho_\alpha = \frac{\mathcal{I}_\alpha(\rho)}{p_\alpha}. \tag{37}$$

This modern operational formulation synthesizes the Born rule and measurement update into a single object (Born, 1926, Davies and Lewis, 1970, Kraus, 1983, Nielsen & Chuang, 2010, von Neumann, 1932).

(ii) Admissible open evolution as channels. Between interventions, the boundary state evolves by a (typically time-ordered) family of quantum channels $\Phi_{t,s}$, i.e. completely positive trace-preserving (CPTP) maps:

$$\rho(t) = \Phi_{t,s}(\rho(s)), \qquad \Phi_{t,s} \text{ CPTP}. \tag{38}$$

CPTP is the minimal mathematical encoding of "physicality" for open evolution (no negative probabilities) (Choi, 1975, Kraus, 1983). Time-homogeneous Markovian evolution is described by a semigroup $\Phi_t = e^{t\mathcal{L}}$.

(iii) Bulk→boundary map as structure-preserving functor. *This paragraph is written for readers with a background in category theory. Its content is a pointer to the literature, not a step in the constitutional argument; nothing later in this paper depends on it.*

A compact way to make OGGEP precise is to view it as a functor between categories:

Definition 5 (Bulk and operational categories)**.** Let **Bulk** be the category whose objects are admissible bulk packages $B = (\mathcal{M}_6, g, \mathcal{A}, \ldots)$ and whose morphisms include diffeomorphisms, gauge transformations, and coarse-graining/RG maps. Let **Op** be the category whose objects are operational boundary packages $O = (\mathcal{H}, \rho, \{\mathcal{I}_\alpha\}, \{\Phi_{t,s}\}, \ldots)$ and whose morphisms are operational equivalences (unitary conjugations, classical relabelings, coarse-grainings).

Definition 6 (OGGEP map)**.** OGGEP asserts the existence of a functor

$$\mathcal{D} : \mathbf{Bulk} \to \mathbf{Op}, \tag{39}$$

that is compatible with:

1. gauge covariance (bulk gauge equivalences map to operational equivalences),
2. causality (retardedness, AX-1),
3. positivity/physicality (channels and instruments preserve state positivity),
4. and, with POS-RG (§18), commutation with coarse-graining.

7.3 Forced consequences / derivations

Derivation 1 (LC + CPTP semigroup ⇒ GKLS/Lindblad generator). Assume: (i) forward-time semigroup property (11) (from LC and Markovity), (ii) complete positivity and trace preservation for each Φ_t, and (iii) mild continuity in t. Then the generator $\mathcal{L}$ has GKLS form (Gorini et al., 1976, Lindblad, 1976):

$$\frac{d\rho}{dt} = \mathcal{L}(\rho) = -i[H,\rho] + \sum_j \left(L_j \rho L_j^\dagger - \frac{1}{2}\{L_j^\dagger L_j, \rho\} \right), \tag{40}$$

with Hermitian H and Lindblad operators L_j.

Derivation 2 (measurement as a special CPTP map with classical output). Each instrument map $\mathcal{I}_\alpha$ in (35) is CP; the total map $\sum_\alpha \mathcal{I}_\alpha$ is CPTP. Thus "measurement" is not a new dynamical law beyond open-system evolution; it is a particular CP update with a registered classical outcome α. This reframes "collapse" as the operational bookkeeping of conditioning on an outcome, consistent with the quantum-instrument formalism (Davies and Lewis, 1970, Kraus, 1983, Ozawa, 1984). The bookkeeping acquires its dynamical completion downstream: *which* outcome actualizes in a given run, and *why* the record persists, are answered by the runtime of Derivation 4 — the GRIP-In halt at a Geometric Attractor — in the dedicated treatment of Arisaka (2026, A8-QM), while the outcome *measure* stays exactly where this paragraph puts it, with the instrument formalism.

Derivation 3 (OGGEP as the operational closure of quantum theory). Standard axiomatizations of QM typically treat unitary evolution as primary and measurement as additional. OGGEP inverts the emphasis: the theory is only complete when the operational map is specified. This is not a claim to new measurement mathematics; it is a claim that measurement should be *constitutional* in any theory that aims to apply across open systems (chemistry, life, mind) (Breuer & Petruccione, 2002, Nielsen & Chuang, 2010).

Derivation 4 (OGGEP ⇒ GDOS ⇒ GRIP: the boundary descent chain). The three derivations above are local consequences of AX-3 — a generator form, a measurement semantics, a closure principle. The global consequence deserves to be stated in the constitution itself, because the entire boundary side of GG-Theory descends from this one axiom in three forced steps, each proved in its own companion paper and none requiring any assumption beyond AX-1–AX-4 and POS-1–POS-7. *Step 1 (the law).* AX-3 demands the operational dictionary $\mathcal{D}$ for *every* admissible open system. Demanding it uniformly — one dictionary, all systems, all scales, commuting with coarse-graining (POS-RG) — forces a single universal boundary law: the reduced open-system dynamics GDOS, with its scalar ledger and four-current Ward package (Arisaka, 2026, A5-GDOS). GDOS is not an extra theory; it is what $\mathcal{D}$ looks like when written out in full. *Step 2 (the runtime).* The long-time behavior of the GDOS flow factorizes — provably, not by construction — as the Gauge-Runtime Invariance Pipeline,

$$\mathsf{AX\text{-}3\ (OGGEP)} \longrightarrow \mathcal{D} \longrightarrow \underbrace{\mathsf{GDOS}}_{\text{the law}} \longrightarrow \underbrace{\mathsf{GRIP} := \mathsf{DGI} \to \mathsf{GSSB} \to \mathsf{GA/GGA}}_{\text{the runtime}} \longrightarrow \underbrace{\mathsf{GGA}}_{\text{the halt}}, \tag{41}$$

with the terminus refined to the Ground Geometric Attractor and the dynamics operating in exactly two regimes — GRIP-In, descent on a fixed landscape, and GRIP-Out, the transient event that reorganizes the landscape itself (Arisaka, 2026, A6-GRIP). *Step 3 (the selector and the readings).*

Which attractor the runtime halts on is fixed by the four admissibility pillars of Arisaka (2026, A7-Qi4) (the GGA selector); the quantum-mechanical face of the chain — quantization, decoherence, and measurement as GRIP phenomena — is developed in Arisaka (2026, A8-QM); and the regime theorems and the cascade-wide ground-state statement are proved in Arisaka (2026, A11-Origin). In one constitutional sentence: *OGGEP demands the dictionary; GDOS writes it; GRIP runs it; and the GGA is where it halts.* Nothing in the chain is postulated beyond AX-3 itself — which is precisely the point: the constitution does not contain a runtime axiom, and Eq. (41) is the proof that it does not need one.

Synthesis (what time is, and who owns the arrow). Read jointly, the first three axioms are the grantors of time's four endowments. AX-1 gives time its *order*: the cone sorts the world. AX-2, through Theorem 0 of (Arisaka, 2026, A2-GG6), gives time its *repetition*: the constitutional clock is a Killing flow, and a time that did not repeat could not tick. AX-3 gives time its *openness* twice — once irreversibly, since the OGGEP projection is one-way and records accumulate (the arrow enters this physics at the level of law, in the same axiom that defines what observation is), and once analytically, since the positivity clause makes the clock's spectrum one-sided and opens the half-plane of lawful continuation (the analytic shore). Time is the unique direction of the arena carrying all four endowments at once: it orders, it repeats, it opens one way, and it opens the shore. The consolidated development is Part IX of the CPT member paper (Arisaka, 2026, P5-CPT), at the grade stated there. And the custody is constitutional: *AX-3 owns the arrow — the one-way reading of the dictionary is a clause of this constitution, not an emergent property; Part IX of the CPT member paper (Arisaka, 2026, P5-CPT) is the canonical law-level derivation of the arrow from this axiom, over a bulk that is itself exactly T-symmetric; the GDOS companion (Arisaka, 2026, A5-GDOS) is its dynamical implementation; and every downstream consumer of an arrow — thermodynamic, cosmological, or biological — points here rather than deriving a private one.*

7.4 Further mathematical elaboration: instruments, Stinespring dilation, and the bulk→boundary dictionary

AX-3 is easiest to audit when written in dilation form. Any instrument $\{\mathcal{I}_m\}$ admits a Stinespring/Naimark representation: there exists an environment Hilbert space $\mathcal{H}_E$, an initial environment state σ_E, a unitary U on $\mathcal{H} \otimes \mathcal{H}_E$, and a pointer POVM $\{\Pi_m\}$ on $\mathcal{H}_E$ such that

$$\mathcal{I}_m(\rho) = \mathrm{Tr}_E\Big[(\mathbf{1} \otimes \Pi_m)\, U\, (\rho \otimes \sigma_E)\, U^\dagger\Big]\,. \tag{42}$$

Equation (42) makes "measurement" concrete: a measurement is a lawful open interaction plus a readout. Different experimental claims correspond to different (U, σ_E, Π_m), and OGGEP requires that the intended protocol be specified.

In the GG-Theory language, the operational dictionary $\mathcal{D}$ is a compiler from *bulk structure* to such boundary instruments. Schematically,

$$\mathcal{D}: \ (\text{bulk fields, ports, geometry}) \longmapsto (\{\mathcal{I}_m\},\ \text{estimator},\ \text{error model}), \tag{43}$$

with LC enforcing causality (no advanced response) and CP enforcing physicality. This rephrases the "measurement problem" as a missing-map problem: not "how does the wavefunction collapse?" but "which CPTP instrument does the theory assign to the laboratory protocol, and what falsifier does it imply?"

A practical consequence is that ambiguity about the "Heisenberg cut" becomes a *controlled approximation*: different coarse-grainings correspond to different effective instruments, and POS-RG will demand that the dictionary commute with the coarse-graining map (so that the claim is not resolution-dependent).

7.5 Worked example: Stern–Gerlach measurement via Stinespring dilation

The Stern–Gerlach experiment is the worked example par excellence for AX-3 OGGEP: a spin-1/2 silver atom enters a magnetic gradient and emerges along one of two trajectories that are then registered by a photographic plate. The experiment is a laboratory realization of an instrument $\{\mathcal{I}_+, \mathcal{I}_-\}$ on the qubit Hilbert space $\mathcal{H}_S = \mathbb{C}^2$ of the silver atom's spin. We shall now show how AX-3 OGGEP forces this instrument to be a CPTP channel plus a classical readout, with the bulk-to-boundary projection of the OGGEP functor realized exactly by the Stinespring dilation theorem of Stinespring (1955).

Consider the joint system: the qubit S together with a pointer register $\mathcal{H}_E = \mathbb{C}^2$ whose two basis states $|0\rangle_E, |1\rangle_E$ correspond to the two possible photographic-plate spots. The atom-pointer interaction is the controlled-not unitary

$$U \;=\; |+\rangle\langle+|_S \otimes \mathbf{1}_E \;+\; |-\rangle\langle-|_S \otimes X_E, \tag{44}$$

where X_E flips the pointer. The pointer is initialized to $|0\rangle_E$, the qubit is in some state ρ, and the combined state $\rho \otimes |0\rangle\langle 0|_E$ evolves unitarily under U. We then read out the pointer in the $\{|0\rangle_E, |1\rangle_E\}$ basis. The resulting two instruments are

$$\mathcal{I}_\pm(\rho) \;=\; \mathrm{Tr}_E\Big[(\mathbf{1}_S \otimes |\pm\rangle\langle\pm|_E)\, U\,(\rho \otimes |0\rangle\langle 0|_E)\, U^\dagger\Big], \tag{45}$$

each $\mathcal{I}_\pm$ a completely positive map on ρ, and $\mathcal{I}_+ + \mathcal{I}_-$ trace-preserving. The associated POVM elements are $E_+ = |+\rangle\langle+|_S$ and $E_- = |-\rangle\langle-|_S$, and the Born rule $P(\pm \mid \rho) = \mathrm{Tr}(E_\pm \rho)$ follows directly from the trace.

Here is the axiomatic reading. AX-3 OGGEP does not *add* a measurement postulate on top of unitary evolution; it *forces* the operational dictionary $\mathcal{D}$ to produce exactly the instrument structure of Eq. (45) as a theorem (specifically, T2 Operational Closure, proved in GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Theorem T2; the CPTP instrument form is that paper's Theorem T3). The Stinespring dilation theorem (Choi, 1975, Kraus, 1983, Stinespring, 1955) guarantees that every CPTP channel admits a dilation of this kind — a unitary on a larger Hilbert space followed by a partial trace. The GG-Theory program inverts the textbook order: instead of postulating the Born rule and the projection postulate as independent axioms, it postulates OGGEP at the constitutional level and derives the instrument structure as a consequence (Arisaka, 2026, A5-GDOS). The Stern–Gerlach result is not a separate phenomenon to be explained by a separate measurement postulate — it is what happens whenever the bulk-to-boundary functor is asked to register an outcome at the boundary. Figure 5 shows the bulk-to-boundary projection schematically.

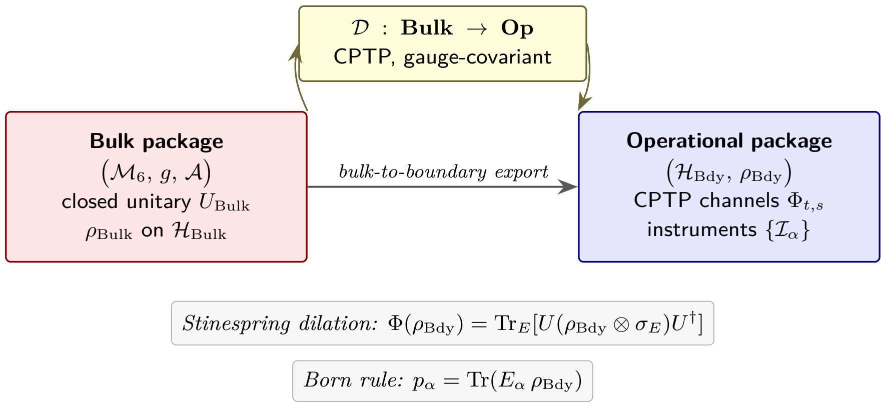

Figure 5: The OGGEP bulk-to-boundary projection from the bulk package $(\mathcal{M}_6, g, \mathcal{A})$ with closed unitary evolution U_{Bulk} (left, red) to the operational package $(\mathcal{H}_{\text{Bdy}}, \rho_{\text{Bdy}}, \Phi_{t,s}, \{\mathcal{I}_\alpha\})$ on the 4D boundary (right, blue), realized by the bulk-to-boundary functor $\mathcal{D} : \textbf{Bulk} \to \textbf{Op}$ (center, orange) that is CPTP and gauge-covariant. Every laboratory measurement is a Stinespring dilation of some CPTP channel followed by a pointer readout, with the Born rule $p_\alpha = \text{Tr}(E_\alpha \rho_{\text{Bdy}})$ supplied by the trace of the dilation. Openness must be the foundational law — and closure becomes its closed-system limit.

7.6 Physics intuition

Remark 3 (Physics intuition for AX-3)**.** Roughly speaking, OGGEP says that there is no physics without an observation compiler. A bulk theory that cannot tell you what an instrument will register is not a physical theory, however elegant its equations may look. In the GG-Constitution, the bulk is like a program and the operational dictionary $\mathcal{D}$ is the compiler that turns it into experimental records. This removes the century-old ambiguity around "measurement" by definition — measurement *is* the operational export $\mathcal{D}$, no more and no less. Every instrument that has ever been calibrated in a physics laboratory is a Stinespring dilation of some CPTP channel; OGGEP is the axiomatic move that promotes that empirical fact to a foundational law. After all, openness must be the foundational law — and closure becomes its closed-system limit.

7.7 Relation to GG-6 and GDOS

- **Relation to GG-6.** GG-6 supplies the bulk structure (geometry+gauge) that $\mathcal{D}$ acts on. In particular, holography-inspired bulk geometries provide a natural environment for such a dictionary (Maldacena, 1998, Susskind, 1995, 't Hooft, 1993, Witten, 1998).
- **Relation to GDOS.** GDOS is the systematic boundary-side expression of $\mathcal{D}$: it provides the general form of admissible open evolution (quantum GKLS, classical Fokker–Planck/Langevin-like limits), and it provides the "ports" and system-instance packets that define measurement protocols (Arisaka, 2026, A5-GDOS, Breuer & Petruccione, 2002).

8 AX-4: MSMF (Maximum Symmetry, Minimum Freedom)

8.1 Constitutional statement (rigorous)

Axiom 4 (AX-4 (MSMF): Maximum Symmetry, Minimum Freedom)**.** *Among all candidate theories consistent with AX-1–AX-3 (and with the postulates of §13), Nature selects those that (i) maximize admissible symmetry and (ii) minimize non-forced freedom. Equivalently: no continuous parameters, moduli, or normalization dials are permitted unless they are strictly forced by symmetry, topology, anomaly cancellation, or operational necessity. When discrete invariants exist, Nature selects the minimal non-degenerate integer/ratio values compatible with the constitution.*

The axiom is intentionally deterministic: it denies that the deep architecture of physics is accidental tuning.

8.2 Mathematical kernel

The axiom can be expressed as an ordering principle on the space of admissible theories.

(i) Candidate set. Let $\mathfrak{T}$ be the set of all *admissible* bulk–boundary packages $T = (B, \mathcal{D})$ satisfying AX-1–AX-3 and the postulates (POS stack). (Here B encodes bulk data, and $\mathcal{D}$ encodes operational export.)

(ii) Symmetry measure. Let $\mathrm{Aut}(T)$ denote the automorphism group of T (bulk isometries and gauge symmetries compatible with the operational map). A convenient proxy for "how symmetric" is

$$S(T) \; := \; \dim \mathrm{Aut}(T), \tag{46}$$

though other monotone measures (e.g. symmetry algebra rank) could be used.

(iii) Freedom measure (moduli/knobs). Let $\mathcal{M}(T)$ be the moduli space of physically inequivalent continuous deformations of T that preserve the axioms (after quotienting by gauge/diffeomorphism redundancies). Define

$$F(T) \; := \; \dim \mathcal{M}(T), \tag{47}$$

or more generally a weighted count of continuous parameters that change operational predictions. In practice, F counts "free parameters" that would otherwise be fitted to data.

(iv) Lexicographic selection (MSMF). MSMF is implemented as the lexicographic optimization

$$T_\star = \arg\max_{T \in \mathfrak{T}} \Big(S(T), -F(T) \Big), \tag{48}$$

meaning: maximize symmetry first; among ties minimize freedom.

8.3 Forced consequences / derivations

Derivation 1 (MSMF as an anti-landscape rule). Suppose $\mathfrak{T}$ contains a continuous family $T(\lambda)$ of physically inequivalent admissible theories, with $\lambda \in \mathbb{R}$ and operational predictions varying with λ. Then $F(T(\lambda)) \geq 1$, and MSMF forbids this family unless λ is forced by the constitution. Thus large "landscapes" of continuously tunable solutions are axiomatically disfavored. This responds to the long-standing concern that unification frameworks can become underconstrained by principle alone (Polchinski, 2004, Susskind, 1979, THooft, 1980).

Derivation 2 (MSMF pushes conventions into postulates). Many continuous "parameters" are actually conventions (choices of normalization, scheme, basis). MSMF demands that such freedoms be explicitly fixed by an axiomatic rule rather than left implicit. In GG-Theory, this is implemented downstream by POS-OGN (Occam gauge normalization) and by a strict separation between redundancy (gauge) and freedom (physical parameters).

Derivation 3 (MSMF turns symmetry breaking into a selection problem). In standard particle physics, spontaneous symmetry breaking is often treated as the selection of a vacuum within a potential landscape. MSMF reframes the question constitutionally: symmetry breaking patterns are admissible only if they are forced by the minimal freedom rule, which becomes especially powerful for open systems (GDOS) where attractors and phase selection generalize the notion of "vacuum" (Arisaka, 2026, A5-GDOS). (The detailed open-system symmetry-breaking story is developed in the companion GDOS paper.)

Derivation 4 (Open-system minimal drift template; GDOS preview). A recurring export from "maximum symmetry, minimum freedom" is that many open-system laws can be written in a *minimal constitutive form* once positivity, invariance, and a choice of ledger are fixed. In a classical mesoscopic limit, let $p(x,t)$ be a probability density on a state manifold $\mathcal{X}$. A generic positivity-preserving Markov generator can be written in Fokker–Planck form (Gardiner, 2009, Risken, 1989)

$$\partial_t p(x,t) = -\nabla \cdot \big(b(x)\, p(x,t)\big) + \frac{1}{2}\nabla \cdot \big(D(x)\, \nabla p(x,t)\big)\,, \tag{49}$$

equivalently as an Itô SDE

$$dX_t = b(X_t)\, dt + \sigma(X_t)\, dW_t, \qquad D = \sigma\sigma^\top, \tag{50}$$

where b is the drift, D the diffusion tensor, σ a noise amplitude, and W_t a Wiener process. Given a chosen ledger functional F (free-energy-like, in the GFF sense) and mobility tensor $M \succeq 0$, a minimal decomposition consistent with steady-state cycling is

$$b(x) \;=\; -M(x)\, \nabla F(x) \;+\; u(x), \qquad \nabla \cdot \big(u(x)\, p_*(x)\big) = 0, \tag{51}$$

where u is a solenoidal (non-gradient) component with respect to the stationary measure p_*. This is not asserted as a domain-specific law; rather it is a *candidate universal template* that survives the admissibility filters (GI/CP/RG) while minimizing non-forced structure—precisely the role of MSMF in a cross-domain open-system setting (Seifert, 2012).

8.4 Further mathematical elaboration: MSMF as an ordering on theory space and a penalty functional

AX-4 can be operationalized as an *ordering* on candidate theory classes. Let $S(T)$ be a symmetry score (e.g. $\dim \mathrm{Aut}(T)$ or another monotone measure of invariance) and let $F(T)$ be a freedom score (e.g. the number of independent continuous parameters/moduli remaining after quotienting gauge redundancies). A minimal "auditor's" ordering is lexicographic:

$$T_1 \prec T_2 \iff (S(T_1) > S(T_2)) \;\text{ or }\; (S(T_1) = S(T_2) \text{ and } F(T_1) < F(T_2)), \tag{52}$$

which encodes "maximize symmetry, then minimize freedom."

For quantitative model selection and textbook discussion, it is useful to package MSMF into a penalty functional that resembles minimum-description-length or information-criterion objectives (Akaike, 1974, Rissanen, 1978):

$$\mathcal{J}(T) := -S(T) + \lambda\, F(T) + \mathcal{C}_{\text{protocol}}(T), \tag{53}$$

where $\mathcal{C}_{\text{protocol}}$ denotes the "cost" of the operational dictionary and falsifiability contract (MF). The constant λ is not a tunable physics parameter; it is a bookkeeping device expressing the structural preference. The conceptual point is that freedom is penalized *unless* it is forced by symmetry, consistency, or operational meaning.

In practice, MSMF interacts directly with POS-OGN: even when two descriptions are physically equivalent, a theory can acquire spurious knobs via continuous basis drift (especially in Abelian sectors). OGN removes that drift by fixing a canonical integer/rational normalization so that "choice of units/basis" cannot masquerade as new physics.

8.5 From the parameter axis to the primitive-category axis: the structure cost and the real-category lemma

The discipline just stated — freedom is penalized unless forced — has so far been applied to *parameters*: continuous couplings, moduli, normalization dials. The same discipline applies to a deeper choice that most frameworks never audit: the *primitive field category* of the bulk — whether the fields of the fundamental description are real, complex, or quaternionic objects. The Foundations Branch (Arisaka, 2026, P4-Real; Arisaka, 2026, P5-CPT) supplies the theorems that make this axis auditable; the present subsection prices it with AX-4's own machinery — the candidate set $\mathfrak{T}$, the scores $S(T)$ and $F(T)$, and the lexicographic selector of Eqs. (46)–(48). One feature of the kernel matters especially here: the admissibility predicate (T satisfies AX-1–AX-3 and the POS stack) is stated *before* any field category is chosen, which is exactly what lets the cost below be defined without presupposing the answer.

Definition 7 (**D-Constitution-1**: structure cost of a primitive field category)**.** For an admissible package $T = (B, \mathcal{D}) \in \mathfrak{T}$, a *structure datum* is a mathematical object that must be specified on the bulk side before the dynamics and the dictionary are defined. A structure datum is *unforced* if at least two inequivalent specifications satisfy AX-1–AX-3 and the postulate stack, with the choice between them not fixed by any axiom, postulate, or already-admitted theorem at the point of specification. The *structure cost* of T's primitive field category is the pair

$$C(T) \;:=\; \Big(\dim\{\text{continuous unforced structure data}\},\ \#\{\text{discrete unforced structure data}\}\Big), \tag{54}$$

ordered lexicographically, and it enters AX-4 as the refinement $\widehat{F}(T) := F(T)+C(T)$: the continuous part adds to the freedom score (47), and the discrete part is adjudicated by AX-4's existing discrete-invariant clause.

Why the cost is not circular. C never mentions $\mathbb{R}$, $\mathbb{C}$, or $\mathbb{H}$, and it never mentions "simplicity." It counts *choices whose alternatives the axioms themselves cannot distinguish*, evaluated by the same procedure on every category — the procedure AX-4 already applies to physical parameters (Nature does not hide knobs). A hostile reader who wishes to reject the pricing must argue either that some counted choice is in fact forced, or that some uncounted choice exists in the real category; both are mathematical claims, checkable. The cost is falsifiable arithmetic, not aesthetics.

The pricing of the three categories. The candidates are the associative normed division algebras $\mathbb{R}$, $\mathbb{C}$, $\mathbb{H}$ (octonionic primitives are excluded upstream of the comparison: associativity of composition of admissible instruments — AX-3's channel algebra — restricts to the associative case by the classical Frobenius–Hurwitz classification, an imported external anchor). Write $\mathfrak{T}_{\mathbb{R}}$, $\mathfrak{T}_{\mathbb{C}}$, $\mathfrak{T}_{\mathbb{H}}$ for the corresponding admissible subclasses.

Real primitives: $C = (0, 0)$. Fields are real sections; the dynamics is generated by a real operator on a real solution space; no complex structure is specified as input. Where complex structure appears, it is a *theorem with a uniqueness clause*: the charge circle's quarter-turn is unique up to sign — the commutant of the irreducible weight-n circle action contains exactly the two quarter-turns (T-P4-1(iii)); the causal clock's polar phase is unique among dynamics-commuting positive-energy structures (T-P4-2); and the residual sign is resolved by the handshake — the sign ambiguity of T-P4-1(iii) is resolved by T-P4-2's positivity, and the resolution is the existence of antiparticles (T-P4-3; re-proved as T-P5-A/B/C). Zero unforced choices; every quarter-turn is forced.

Complex primitives: $C \geq (0, n_{\text{sec}} + 1)$ *for* n_{sec} *charged sectors.* A complex-primitive package must specify, as input data with admissible alternatives: (i) the sign of the complex structure J on each charged sector — pre-dynamically, $2^{n_{\text{sec}}}$ inequivalent assignments satisfy AX-1–AX-3, and the Feynman–Stückelberg pairing must then be *postulated* rather than derived (in $\mathfrak{T}_{\mathbb{R}}$ it is T-P4-3's output; in $\mathfrak{T}_{\mathbb{C}}$ it is an axiom — the antiparticle handshake is exactly the content the complex category buys by fiat); (ii) the identification of the gauge i with the dynamical i — "physics has one i" is a theorem in $\mathfrak{T}_{\mathbb{R}}$ (the shared global J of T-P4-3/4) and an unforced global alignment postulate in $\mathfrak{T}_{\mathbb{C}}$; and (iii) the reality conditions — hermiticity of the action, and the selection of the real observable slice for AX-3's registered records, since the boundary registers real numbers. Count: at least one discrete choice per charged sector plus one global alignment choice. The symmetry score does not rescue the category: S ties on shell, because the real category recovers the full complex symmetry (T-P4-4); ties in S are adjudicated by $\widehat{F}$, and $\widehat{F}$ decides for $\mathbb{R}$.

Quaternionic primitives: continuous loss at the first slot, and a double-count. An $\mathbb{H}$-module carries a two-sphere of compatible complex structures (the unit imaginary quaternions $a\mathbf{i} + b\mathbf{j} + c\mathbf{k}$ with $a^2 + b^2 + c^2 = 1$); selecting the physical i within it is a *continuous* two-parameter unforced choice per sector — a modulus in exactly the sense of (47), so $C(\mathfrak{T}_{\mathbb{H}})$ opens with a continuous entry of dimension $2\,n_{\text{sec}}$ and the category loses at the first slot before discrete counting begins. Independently, the mod-8 reality clock of the real Clifford algebra closes the door a second time: the $(1, 5)$ bulk sits at hour $t - s \equiv 4$ — a quaternionic hour — so the pseudo-real spinor structure physics actually uses is already delivered by the real Clifford algebra as derived structure, read off the standard spin-geometry classification (Arisaka, 2026, P5-CPT, App. G.4, where the reading is textbook material). Postulating $\mathbb{H}$-primitives therefore duplicates structure the real category provides as a theorem — the precise spurious-knob pathology that AX-4 MSMF and POS-6 OGN exist to forbid — and, more deeply, inverts a dependency: $\mathbb{C}$ and $\mathbb{H}$ are hours of a *real* clock (the centralizer algebra of $\mathrm{Cl}(t, s)$ cycles through $\mathbb{R}$, $\mathbb{C}$, $\mathbb{H}$ with Bott period eight), so taking them as primitive prices in the whole clock to recover one hour.

Lemma 1 (**L-Constitution-1** (cohort alias L-Real-1), candidate: the real category as the AX-4 minimum)**.** *Let $\mathfrak{T}^{\text{rec}} \subset \mathfrak{T}$ be the subclass of admissible packages from which the observed boundary complex structure — one shared imaginary unit, the complex Hilbert-space representation, the Wick rotation with its statistics and thermal clock, and the particle–antiparticle conjugation — is recoverable at the quasi-free grade. Among the primitive field categories $\mathfrak{T}_{\mathbb{R}}$, $\mathfrak{T}_{\mathbb{C}}$, $\mathfrak{T}_{\mathbb{H}}$, the real category is the unique minimum of the refined AX-4 cost $\widehat{F} = F + C$ on $\mathfrak{T}^{\text{rec}}$:*

(i) Membership (existence): $\mathfrak{T}_{\mathbb{R}} \in \mathfrak{T}^{\text{rec}}$ *— the recovery is exhibited by T-P4-1 through T-P4-7 and T-P5-A/B/C with the Wick quartet T-P5-B1: the circle supplies the gauge i, the clock the state-space i, the handshake their forced agreement (the antiparticle), and the quartet the rotation/statistics/thermal-clock triple from the one-sided spectrum (Arisaka, 2026, P4-Real; Arisaka, 2026, P5-CPT).*

(ii) Minimality: $C(\mathfrak{T}_{\mathbb{R}}) = (0, 0) < C(\mathfrak{T}_{\mathbb{C}}) \leq C(\mathfrak{T}_{\mathbb{H}})$*, by the pricing of D-Constitution-1 above.*

(iii) Uniqueness: *any package achieving cost* $(0, 0)$ *specifies no complex structure as input, hence must derive its J from the constitutional data; by T-P4-2's uniqueness clause (positive-energy, dynamics-commuting, on the globally static arena) and T-P4-3's sign resolution, the derived J is unique — so every zero-cost member of $\mathfrak{T}^{\text{rec}}$ coincides with the real-category construction on shell.*

Consequently, "only real numbers in the 6D bulk" is not an independent postulate of the program: it is the AX-4-selected point of the primitive-category axis, in the same sense in which the absence of continuous coupling dials is the AX-4-selected point of the parameter axis. Scope concessions, stated with the lemma: *clause (i) holds at the quasi-free grade, conditionally beyond it on the named hypotheses (H1)–(H3) of T-P4-8; clauses (ii)–(iii) are constitutional forcing arguments — chains of* *necessity given the axioms — not theorems of constructive QFT; and the restriction to $\{\mathbb{R}, \mathbb{C}, \mathbb{H}\}$ imports the Frobenius–Hurwitz classification.*

Grade: candidate — and why. L-Constitution-1 is graded *candidate*, and the reason should be said plainly: the recoverability leg (i) is derived at the quasi-free grade by inheritance from the cited theorems, but the pricing legs (ii)–(iii) rest on D-Constitution-1's counting of unforced choices — a stated argument, not a proved theorem of constructive field theory. L-Constitution-1 is a constitutional forcing argument in the sense of GG-A2-GG6's Remark 0.5 (Arisaka, 2026, A2-GG6), and every downstream use inherits that register.

F-Constitution-10 (cohort alias F-Real-1; candidate falsifier of L-Constitution-1; registered in Table 7). *The lemma dies if any one of the following is observed.*

(1) *A non-geometric CP phase.* A measured fundamental CP-violating phase demonstrably *not* expressible as real orientation/holonomy data — concretely, a confirmed δ_{CKM} or δ_{PMNS} provably outside every closed-loop lattice angle the real texture calculus admits, *after* the GG-A9-SM QD-class freeze (Arisaka, 2026, A9-SM), which removes the escape of re-tuning (no new unit may be introduced), so a stray phase kills rather than bends. An irreducibly complex Yukawa datum with no dynamical source would break the recoverability clause (i): some observed complex structure would then not be the boundary's name for a real quarter-turn.

(2) *Unshared-i evidence.* A precision-interferometry or correlation experiment establishing that the charge-circle i and the causal-clock i are *not* shared — two inequivalent complex structures that cannot be globally aligned, violating the shared-J recovery of T-P4-4. This is the network-Bell exclusion of real quantum mechanics (Renou et al., 2021) run in reverse: that experiment class excludes *unshared* real tensor products (and is satisfied by the shared-J construction); nature exhibiting sector-dependent imaginary units would kill the shared-J theorem itself.

(3) *Quaternionic-direction Born deviations.* A confirmed deviation from the Born trace form *in the direction of quaternionic amplitudes* — a genuine three-path interference residue of the Sorkin-parameter class (Peres, 1979, Sinha et al., 2010) matching $\mathbb{H}$-amplitude predictions — would indicate that the bulk category is $\mathfrak{T}_{\mathbb{H}}$, killing minimality leg (ii) from the opposite direction. (Deviations in the real-deficient direction — nature poorer than complex — are already excluded by the shared-J reading of Renou et al., 2021; the quaternionic-excess direction is the live kill.)

8.6 Worked example: the 28 free parameters of the Standard Model

A concrete instance brings out the discipline. The cleanest test of AX-4 MSMF is the parameter inventory of the Standard Model. The SM as currently fitted to data carries the following 28 continuous parameters (Particle Data Group, 2024): three gauge couplings (g_1, g_2, g_3 at, say, the Z-pole); two electroweak Higgs-sector parameters (v and λ, equivalently m_W and m_H); nine charged-fermion masses (six quarks, three charged leptons); four CKM parameters (three angles plus one phase); three neutrino masses (or two mass-squared differences plus one absolute scale); four PMNS parameters (three angles plus one Dirac phase, with two further Majorana phases if neutrinos are Majorana); the QCD theta-angle $\bar{\theta}$; the cosmological constant Λ; and the Newton constant G_N. Adding two Majorana phases takes the count to 30 in the most generous reading and dropping the gravitational sector takes it to 26. The "28 parameters" figure is the conventional middle point.

The axiomatic question is: which of these 28 are forced by the GG-Constitution, and which remain free? AX-4 MSMF forbids any continuous parameter unless it is forced by symmetry, topology, anomaly cancellation, or operational necessity. POS-6 OGN further forbids any continuous normalization choice; only the discrete OGN-5 integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ survives. Together, these clauses imply that an admissible candidate theory of the SM must predict every one of the 28 parameters from the constitutional data. The companion paper (Arisaka, 2026, A9-SM) takes up this challenge and shows that all 28 SM parameters descend from the 6D bulk, the four-component anomaly polynomial, and the OGN-5 ledger, with *zero* adjustable continuous inputs. The empirical predictions include:

- the unification scale $E_{\mathrm{GUT}} = E_{\mathrm{Pl}}\, \mathrm{e}^{-2\pi} \approx 2.28 \times 10^{16}\,\mathrm{GeV}$;
- the lock cluster $M_{\mathrm{lock}} = (1/2)\, M_{\mathrm{Pl}}\, \mathrm{e}^{-35} \approx 3.85\,\mathrm{TeV}$;
- the electroweak scale $v = M_{\mathrm{lock}}\,(2/L)^N = M_{\mathrm{lock}}\,(2/5)^3 \approx 246.33\,\mathrm{GeV}$, the doublet projection $2/L = 2/5$ raised to the generation count $N = 3$;
- the cosmological-constant scale $m_\Lambda^{\mathrm{geom}} = M_{\mathrm{lock}}^2/M_{\mathrm{Pl}} \approx 6\,\mathrm{meV}$;
- the cosmological partitions $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$, $\Omega_b = 1/(2\pi^2)$, and $\Omega_{\mathrm{DM}} = 1/\pi - 1/(2\pi^2)$ (Arisaka, 2026, A10-Cosmos);
- the kaxion oscillation frequency $\Delta\nu/\nu = 1/35$.

Each of these is a discrete consequence of the constitution and the integer ledger; none is a fitted parameter. Generally speaking, the axiomatic reading of the 28-parameter inventory is that the Standard Model is not wrong — it is *incomplete* as a foundational document, because the 28 parameters are exactly the unforced freedom that AX-4 MSMF forbids. After all, the axiomatic bargain offered here is that a single short document forces every dial of the Standard Model and ΛCDM to take a specific value. If a single one of the listed predictions is decisively falsified by experiment, the constitution is wrong; if all of them survive contact with data, the GG-Theory program has accomplished what unification has been promising for half a century.

8.7 Physics intuition

Remark 4 (Physics intuition for AX-4)**.** Roughly speaking, MSMF says that Nature does not hide knobs. If a parameter is not forced by symmetry, topology, anomaly cancellation, or operational necessity, it is not allowed to remain fundamental. This is a direct response to the culture of model catalogs with many adjustable constants — the 28 free parameters of the Standard Model, the moduli fields of string compactifications, the tunable inflaton sector of inflationary cosmology. Indeed, an explanation that requires us to choose the value of a continuous dial is not really an explanation; it is a deferred problem. MSMF converts the aesthetic preference for parsimony into an auditable demonstrate-or-eliminate rule: either show that a candidate parameter is forced by the constitution, or remove it from the theory. Together with POS-6 OGN, the rule pins every continuous dial of the inherited foundational physics to a discrete consequence of the OGN-5 integer ledger.

8.8 Relation to GG-6 and GDOS

- **Relation to GG-6.** In GG-6 this axiom demands that the bulk background, gauge group, and discrete topological data be as symmetric and as moduli-free as possible. Combined with anomaly cancellation (POS-AF) and normalization (POS-OGN), this is intended to eliminate continuous free parameters in the unification stage (Arisaka, 2026, A2-GG6).
- **Relation to GDOS.** In GDOS MSMF becomes a constitutive-selection rule for open dynamics: drift/flow terms and noise structures are constrained to be the minimal ones compatible with positivity and gauge invariance. This plays the role of a universal "closure" principle for complex systems (Arisaka, 2026, A5-GDOS).

9 Inter-axiom logic and the first theorems forced by the axioms

The four axioms are designed to be used as a dependency-controlled proof system; let us name the dependency order before the postulates of Part III come into play. The strict ordering is the four-axiom chain

$$\text{AX-1 LC} \implies \text{AX-2 GGEP} \implies \text{AX-3 OGGEP} \implies \text{AX-4 MSMF}, \tag{55}$$

in which each axiom *presupposes* the previous and adds new content. AX-1 sets the admissible causal arrow that any later clause must respect; AX-2 presupposes AX-1 and adds the composite bulk primitive (geometry locked with gauge) that will be projected to the boundary; AX-3 presupposes AX-1 + AX-2 and adds the operational dictionary that turns the bulk primitive into registered boundary records; AX-4 presupposes AX-1 + AX-2 + AX-3 and closes the theory space by eliminating every continuous degree of freedom not forced by the previous three. This strict chain is the same constitutional tower that Part V develops in detail (**Figure 10**), with Stratum N corresponding to the axiom subset $\{\text{AX-1}, \ldots, \text{AX-N}\}$.

Several first theorems have already surfaced in the present Part: AX-1 together with Markovity forces the forward-time semigroup law of Eq. (11); AX-1 together with CPTP forces the GKLS form of the generator (40); AX-2 acting on a compact U(1) holonomy fiber forces the integer-quantized charge spectrum (26); and AX-4 on the candidate-theory space forces the anti-landscape lexicographic selection (48). Part III will now supply the seven postulates that turn these fragments into a full admissibility engine, and Part IV's cross-paper coherence map will pin each of the eleven Principal Theorems T1–T11 to its canonical proof location in the cohort companion paper where its derivation actually lives.

10 Comprehensive summary of AX-1–AX-4

This subsection closes the chapter with three complementary views of the same four axioms, because no single view carries all of what a reader needs.

The first is an *auditor's* view: Table 2 sets out what each axiom asserts, the minimal mathematical kernel it needs, the first consequences it forces, and — the column that matters most — the experimental fact that would make it unusable. It answers the question *what does this axiom say, and how would I know if it were wrong?*

The second is a *structural* view. Figure 6 draws the four axioms as a nested tower and places each major framework of twentieth-century physics on the slab whose axioms it actually uses. It answers a different question: *what does each axiom buy, and what is left unsayable without it?*

The third is a *historical* view. Figure 7 puts eight centuries of physics on a time axis, one lane per axiom, and shows that all four were arrived at piecemeal, by communities that mostly did not know they were working on the same thing. It answers the question a skeptical reader is entitled to ask: *if these four principles are so fundamental, why has nobody written them down before?*

The three views are consistent by construction — the tower's slabs are the table's rows, and the timeline's lanes are the tower's slabs — but they are not redundant, and a reader who takes only one should take the table.

Table 2: Axioms summary (AX-1–AX-4). Auditor-style overview of each axiom: a crisp constitutional clause, representative equations, first forced consequences, and an explicit failure mode. The rightmost column is written as a practical falsifier: what experimental/operational fact would make the axiom unusable.

Axiom	Name	Formal kernel (representative equations)	Forced consequences (first theorems)	Failure mode / falsifier
AX-1	LC	Retarded support of response kernels (7), (9); microcausality (8); forward semigroup (11).	No superluminal signaling in registered statistics; arrow-of-time for open evolution; prerequisite for operational dictionary.	Any experimentally validated operational kernel enabling advanced response/backward influence; acausal signaling in registered records.
AX-2	GGEP	Composite connection $\mathcal{A}$ and curvature $\mathcal{F}$ (3)–(4); holonomy (20); local trivialization (22).	Unified inertial notion (locked chart); geodesic/Lorentz-force unification (24); quantization from compact holonomy (26).	Obstruction to defining a single composite connection with consistent gauge/geometry covariance; need for independent "force primitives" beyond curvature/holonomy invariants.
AX-3	OGGEP	Operational map $\mathcal{D}$ (functor) (39); instruments/POVMs (35)–(37); admissible evolution as CPTP channels; GKLS generator (40).	Measurement defined unambiguously as instrument output; LC+CPTP$\Rightarrow$ Lindblad form; bulk statements become scientific only if they compile to observables.	Inability to construct a causal, gauge-covariant operational dictionary; predicted evolution violates CPTP/-positivity or enables inconsistent measurement semantics.

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Axiom	**Name**	**Formal kernel (representative equations)**	**Forced consequences (first theorems)**	**Failure mode / falsifier**
AX-4	MSMF	Theory-space ordering by symmetry and freedom (46)–(48); moduli count $F(T)$.	Anti-landscape selection: continuous tunable families forbidden unless forced; conventions must be constitutionally fixed (via POS-OGN); symmetry breaking becomes constrained selection.	Operational necessity of continuous moduli/knobs that cannot be eliminated without losing empirical adequacy; parameter landscapes required by data.

The tower: what each axiom buys. The four axioms are not a list of independent assumptions. They are strictly nested, and Figure 6 is drawn to make the nesting the first thing one sees: the chart reads downward, each slab adds exactly one axiom to the slab above it, and the arrow on the left records the only fact the picture is really asserting — that each addition strictly enlarges what can be derived.

The nesting is forced rather than chosen. AX-1 must come first because without a causal ordering there is no sense in which one thing can be said to respond to another, and every later axiom is about a relation between things. AX-2 presupposes AX-1 because a connection is defined by parallel transport along paths, and paths are ordered. AX-3 presupposes AX-2 because there must be a structure to coarse-grain before coarse-graining means anything. And AX-4 presupposes all three, because a selection principle needs a space of admissible theories to select within, and the first three axioms are what define admissibility.

Read the slabs downward and each is a recognizable body of physics. The first produces special relativity and classical field theory on a fixed background — everything that follows from causal propagation alone. The second adds the identification of force with curvature, and with it comes general relativity, Yang–Mills theory, the Green–Schwarz mechanism, superstring theory and the AdS–CFT correspondence: an enormous quantity of physics, all of it obtained from two axioms. The third adds the boundary coarse-graining, and with it the quantum postulates as theorems, classical thermodynamics, statistical mechanics, the fluctuation theorems, black-hole physics and the free-energy principle. The fourth removes the remaining freedom and yields a Standard Model whose twenty-eight fitted inputs are forced and a cosmological model with no tunable inventory.

The diagnostic reading. The tower earns its place here not by what each slab produces but by what each slab *cannot say*. A framework standing on the second slab has no operational layer, and so it has nothing to say about when a measurement has occurred — which is precisely the century-old measurement problem, and precisely why it could not be solved from inside that slab no matter how much technical effort was applied. A framework standing on the third slab has no selection principle, and so it cannot say which of its admissible solutions is realized — which is precisely the landscape problem. In each case the persistent open question of a research program turns out to have the shape of the axiom that program does not have.

This is a claim about logical dependency, and it should not be read as a ranking. Every framework on the tower produced what it produced, and each correctly used the axiom subset its own problems required. General relativity did not need an operational dictionary, because nothing in the classical field equations has to be observed for them to hold. Quantum mechanics did need one, because a probability is by definition what a finite observer registers. The tower does not say that anyone was careless. It says that the fragmentation of twentieth-century theoretical physics into sub-disciplines with separate vocabularies is the visible shadow of working with partial and implicit axiom subsets.

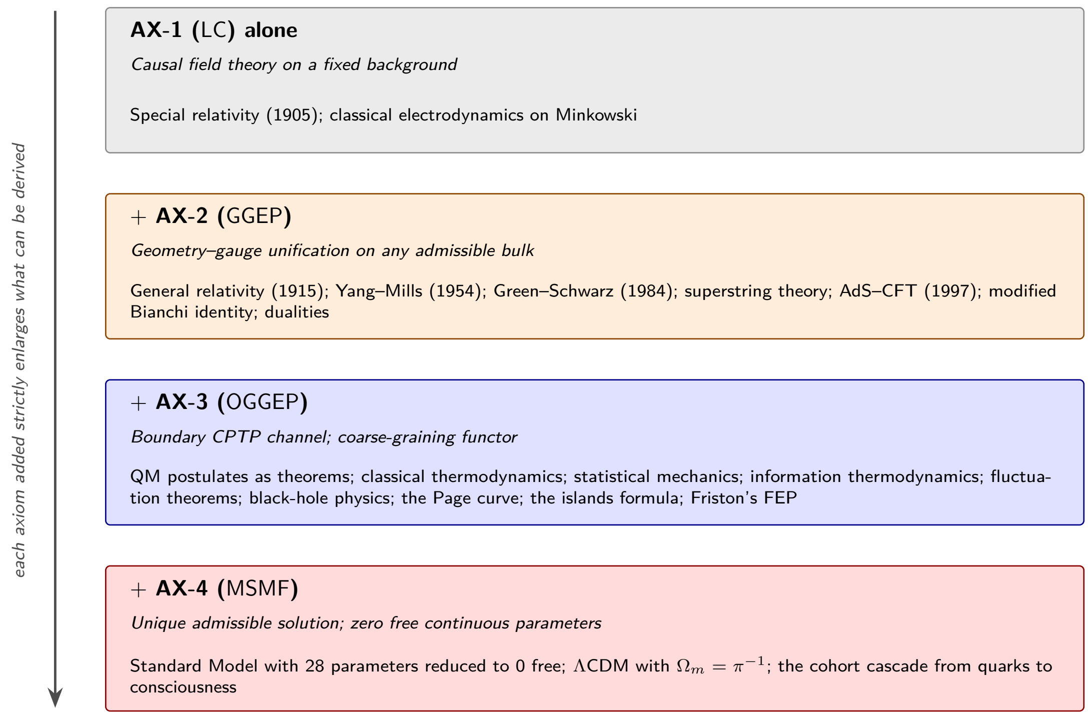

Figure 6: The four axioms as a strictly nested tower. Each slab adds exactly one axiom to the slab above it, and the chart reads downward, so vertical position is logical depth: everything derivable on a slab is derivable on every slab beneath it, and the arrow on the left records that the containment is strict. Each historical framework is placed on the slab whose axioms it actually uses, not the slab its practitioners would have claimed. The reading that matters is the negative one: what a slab cannot say is the content of the axiom it lacks, which is why the measurement problem could not be solved from the second slab and the landscape problem could not be solved from the third. The placement is a statement about logical dependency and not about merit — every framework named here correctly used the axiom subset its own problems required.

The historical record: four threads pulled separately. A reader meeting four constitutional axioms for the first time is entitled to be suspicious of their novelty. If these principles are fundamental, why did nobody state them? Figure 7 is the honest answer: they were all arrived at, piece by piece, over eight centuries — but by separate communities, in separate languages, and never together. Each lane of the chart is one axiom, each dot is a dated and attested result that put part of that axiom into physics, and nothing on the chart is claimed for the present program that its author did not obtain.

The lane for AX-1 is the oldest and the sparsest. Ibn al-Haytham establishes that light travels along definite paths in finite time; Newton's *Principia* makes the question of whether influence is local unavoidable precisely by leaving it unanswered, a dissatisfaction Newton stated himself; Maxwell answers it by replacing action at a distance with a field; and Einstein and Minkowski close the lane by making the causal structure part of the geometry. Five results across nine hundred years, and by 1908 the axiom is complete and has no name.

The lane for AX-2 is the most concentrated. Gauss shows that curvature is intrinsic — that a surface knows its own shape without being embedded in anything — and Riemann generalizes it to any number of dimensions, sixty years before there is a physical use for it. General relativity then makes gravitation a curvature; Weyl, in a theory that failed for other reasons, introduces the gauge idea that makes electromagnetism one too; Kaluza and Klein show that an extra dimension can carry it; Yang and Mills make it non-abelian; Green and Schwarz make it anomaly-free; and Maldacena makes a bulk geometry equivalent to a boundary theory. Eight results in one hundred and seventy years, each visibly building on the last.

The lane for AX-3 is the busiest and the least unified, and this is the chart's most important reading. Eleven results between Carnot and Friston — in classical thermodynamics, in statistical mechanics, in quantum measurement theory, in information theory, in black-hole physics, and finally in theoretical neuroscience. Every one of them is about what a system that cannot see everything can nevertheless say. None of those communities had a name for what they had in common, and several of them were unaware of each other. Landauer's bound (Landauer, 1961) and the Bekenstein–Hawking entropy and Zurek's einselection are, on the reading developed in this paper, three faces of one axiom, and they were obtained twelve years apart by people who would not have described themselves as working on the same problem.

The lane for AX-4 is the oldest and the emptiest, and its shape is the most telling. Ockham states the principle in the fourteenth century; Kepler tries to derive the planetary orbits from pure symmetry and fails; Maupertuis makes minimization a physical principle; Noether makes symmetry a source of conservation laws. After that the lane goes quiet for most of a century — not because the instinct is abandoned, but because it never becomes an axiom. It operates as taste. And the consequence is visible on the right-hand end of the lane: the free-parameter count of fundamental physics falls steadily through the twentieth century — one for general relativity, two for quantum electrodynamics, twenty-eight for the Standard Model, six for the standard cosmological model — and never reaches zero, until a landscape of order 10^{500} vacua makes the absence of a selection principle impossible to ignore.

What the timeline does not claim. It is not a priority claim and it is not a ranking. Every result on the chart stands on its own, is cited in its own right, and would remain true if the present framework were abandoned tomorrow. The chart makes one observation only: four threads were pulled separately for a long time by people who could not see each other's work, and the proposal of this paper is to hold all four at once, as explicit axioms, and see what that forces. The horizontal axis is deliberately broken so that the modern era, where every lane is dense, remains readable; the compressed left-hand fifth carries the four pre-modern anchors that would otherwise be lost.

The three views together. The table says what the axioms assert and how each could fail. The tower says what each one buys and what is unsayable without it. The timeline says that none of them is new, and that what is new is holding them together. A reader who accepts the table has accepted the constitution; a reader who accepts the tower has accepted that twentieth-century physics is one structure rather than several; and a reader who accepts the timeline has accepted only a historical observation, which is the least the three demand and the easiest to check.

11 The most consequential immediate implication of the four axioms

Before the seven postulates of Part III refine the four axioms into runtime admissibility filters, it is worth pausing for the one consequential implication that the four axioms — taken together as the constitutional charter — *immediately* settle. This is not an aesthetic claim; it is the structural fact that distinguishes the cohort framework most sharply from its twentieth-century predecessors, and it is the item we would most like the broader physics community to take away from the present paper.

The century-old measurement problem is finally solved by AX-3 OGGEP. For ninety years — from the von Neumann *Mathematische Grundlagen* of 1932 (von Neumann, 1932) through Bell's 1964 inequality (Bell, 1964), the decoherence program of Zeh, Joos, and Zurek (Joos & Zeh, 1985, Zeh, 1970, Zurek, 1981, 2003), and the islands formula of Almheiri–Engelhardt–Marolf–Maxfield and Penington–Shenker–Stanford–Yang (Almheiri et al., 2019, Penington et al., 2022) — the measurement problem has been the most awkward open seam in physics. Every standard textbook closes its chapter on quantum mechanics with a hedged sentence about "the role of the observer" or "the interpretation of the wave function," and the ninety-year debate has produced no consensus resolution within the conventional axiomatic framework.

AX-3 OGGEP resolves it. **Every system in nature is an open system.** This single empirical fact, elevated to a constitutional axiom, dissolves the von Neumann cut by definitional fiat: measurement *is* the always-on bulk-to-boundary projection $\mathcal{D}$, gauge-covariant and CPTP, with the boundary record produced as the output of the operational dictionary rather than as a separately-postulated collapse. The textbook QM postulates — the Born rule, the Lüders projection, decoherence, einselection, and Bell–CHSH violation — become theorems of $\mathcal{D}$ acting on the bulk (the chain T7.1–T7.7 proved in GG-A5-GDOS (Arisaka, 2026, A5-GDOS), exercised at graduate-textbook depth in GG-A8-QM (Arisaka, 2026, A8-QM)). The Heisenberg cut is dissolved; the von Neumann chain is terminated at the first macroscopic pointer state with a record-amplification chain sufficient for the experimenter's purpose; Wigner's friend (Wigner, 1961) is resolved by the always-on projection's independence from any particular observer. The ninety-year measurement-problem debate becomes, concretely, the seven-theorem chain T7.1 (Hilbert-space embedding) → T7.2 (Schrödinger equation) → T7.3 (Born rule) → T7.4 (Lüders projection) → T7.5 (decoherence) → T7.6 (einselection) → T7.7 (Bell–CHSH violation), each derived inside GG-A5-GDOS from AX-3 OGGEP acting on the bulk. Ninety years of interpretational debate compile into seven

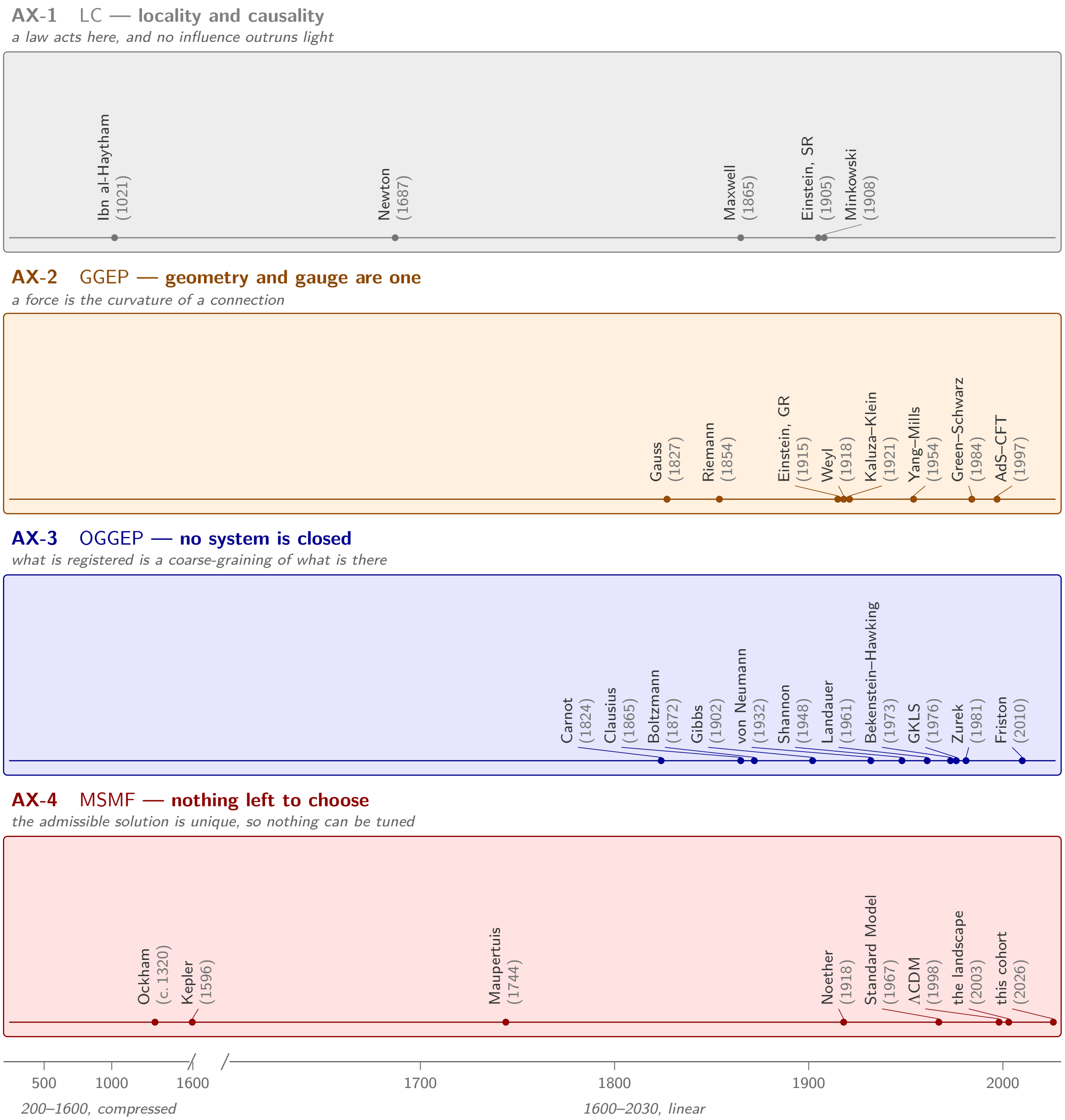

Figure 7: The four axioms in historical order. Each lane is one axiom and each dot is a dated result that put part of that axiom into physics before anyone had named it; the lanes are ordered as the axioms are. Read across a lane and it is a research tradition; read down a column and it is a period. Three features carry the argument. The AX-3 lane is by a wide margin the busiest and the least unified — eleven results across two centuries, in thermodynamics, information theory, black-hole physics and neuroscience, none of whose communities had a name for what they shared. The AX-2 and AX-3 lanes run in parallel for a century and almost never touch. And the AX-4 lane is the oldest and the emptiest: Ockham states the principle in the fourteenth century, after which it operates as taste rather than as an axiom, which is why the free-parameter count of the twentieth century falls steadily and never reaches zero. The horizontal axis is broken — 200–1600 is compressed into the left-hand fifth — so that the modern era, where every lane is dense, stays legible. Positions are the accepted dates of publication.

theorems once the right axiom is named.

This is, *the most significant immediate contribution* of the GG-Constitution. The constitution does many other consequential things — it locates every major twentieth-century theoretical-physics framework inside a four-axiom tower (Part V), it forces a unique vacuum from a $\sim 10^{500}$-vacuum landscape (§33), it derives the 28 Standard Model parameters as a discrete consequence of the integer OGN-5 ledger (GG-A9-SM (Arisaka, 2026, A9-SM)). But none of those downstream consequences carries the same *immediate* impact on the broader physics community as the recognition that the measurement problem, which has resisted resolution within the conventional axiomatic framework for ninety years, is settled by the single act of writing AX-3 OGGEP as a constitutional axiom. After all, every body of knowledge becomes a science when its practitioners agree on what counts as an observation; physics has carried that agreement quietly for ninety years, and AX-3 OGGEP puts it on the page.

12 Century-old history of the four axioms

The four axioms did not arrive from nowhere. Each one is the sharpened form of a question the twentieth century asked and answered only in part, and each was argued over for decades before it could be written in a line. This Section collects that history, axiom by axiom, so that the constitutional statements above can be read as the end of a long argument rather than as assertions made in a vacuum.

12.1 AX-1: LC (Locality and Causality)

Locality and causality are constitutional pillars inherited from the longest-running thread in the history of physics. In keeping with the systematic presentation we adopt for the other axioms, we organize the AX-1 lineage as twelve chronological milestones whose structural content AX-1 LC distils into a single axiomatic clause. Each milestone is also located in Part V's constitutional tower (**Figure 10**): the AX-1-alone Stratum-1 frameworks (special relativity and classical electrodynamics) live entirely within the locality-and-causality content this Section credits.

(1) Galileo — the principle of relativity (1632). Galileo's *Dialogo* of 1632 (Galilei, 1632) contains the first explicit statement of the relativity principle: the "ship's cabin" thought experiment shows that mechanics inside a uniformly moving ship is indistinguishable from mechanics at rest, hence no inertial frame is preferred. Galileo's insight is the kinematic ancestor of AX-1 LC: any admissible kernel must respect a kinematic invariance group, and operational registrations made in different inertial frames must be consistently relatable.

(2) Newton — the first modern propagation framework (1687). Newton's *Principia* (Newton, 1687) established the first modern framework in which physical effects propagate from cause to effect through space, though Newton himself remained famously uneasy that gravitational action appeared to act instantaneously across arbitrary distances — a tension he called *"so great an absurdity that I believe no man, who has in philosophical matters a competent faculty of thinking,* *can ever fall into it."* The Newtonian framework is the historical baseline against which every later refinement of locality and causality has been measured.

(3) Maxwell and Lorentz — finite-speed propagation (1865, 1904). Maxwell's electromagnetic theory (Maxwell, 1865) resolved Newton's instantaneous-action tension for electromagnetism by showing that disturbances of the field propagate at finite speed. Lorentz's 1904 paper (Lorentz, 1904) introduced the transformations that bear his name — the symmetry group under which Maxwell's equations are form-invariant. Together, Maxwell and Lorentz set the stage for special relativity by showing that finite-speed propagation is not a feature of one theory but a candidate kinematic primitive for all theories.

(4) Einstein — special relativity elevates finite speed to a universal constraint (1905). Einstein's 1905 paper (Einstein, 1905) elevated finite-speed propagation to a universal kinematic constraint: the speed of light is the same in every inertial frame, and no signal carries information faster. In Part V's classification, special relativity is the canonical Stratum-1 framework: it lives entirely within AX-1 LC alone, requiring no gauge structure (AX-2), no operational projection (AX-3), and no minimality principle (AX-4).

(5) Minkowski — the light cone as geometric structure (1908). Minkowski (Minkowski, 1908) recast Einstein's kinematic constraint as the geometric structure of the light cone — the first time causal ordering was treated as a property of spacetime itself rather than of particular dynamical laws. Minkowski's move is the conceptual ancestor of AX-1 LC's reading of the bulk causal structure as a primitive of the manifold rather than a derived feature of the dynamics.

(6) Einstein — general relativity internalizes causality in spacetime curvature (1915–1916). Einstein's general relativity (Einstein, 1915, 1916) internalized causality into the curvature of spacetime: the metric $g_{\mu\nu}$ itself encodes both the gravitational field and the local causal structure. General relativity is the $\{\mathsf{AX\text{-}1}, \mathsf{AX\text{-}2}\}$ Stratum-2 specialization that adds the geometry-gauge equivalence content of AX-2 GGEP (here in its gravity-only specialization) on top of the locality and causality content of AX-1 LC.

(7) Wightman and Streater–Wightman — microcausality as a QFT axiom (1956, 1964). Wightman (Wightman, 1956) and Streater–Wightman (Streater & Wightman, 1964) formulated the microcausality axiom (8) that fields commute at spacelike separation; the Wightman axioms are the first rigorous axiomatization of relativistic quantum field theory in which locality and causality appear as constitutional clauses rather than as background assumptions. AX-1 LC is the cohort generalization of the Wightman microcausality axiom to the open, operational setting of AX-3 OGGEP.

(8) Haag and the algebraic-QFT school — locality of operator algebras (1964–1996). Haag (Haag, 1992) and the algebraic-QFT school developed the Wightman framework into the local-net formulation, in which the observable algebra is assigned to spacetime regions with strict commutativity at spacelike separation. The algebraic-QFT tradition is the most mature mathematical realization of AX-1 LC in the closed-system regime; the cohort framework extends it to the open-system regime via AX-3 OGGEP.

(9) Bell and Tsirelson — locality and its quantum bound (1964, 1980). Bell (Bell, 1964) made causality and locality empirically testable: his celebrated inequality showed that a wide class of locally causal hidden-variable theories make quantitative predictions distinguishable from those of standard quantum mechanics. Tsirelson (Tsirelson, 1980) sharpened the constraint by proving the quantum upper bound $|S| \leq 2\sqrt{2}$: quantum mechanics maximally violates the classical-local-causality bound, but only up to a specific saturation. AX-1 LC accommodates Bell-violating correlations within the Tsirelson bound while still forbidding superluminal signaling, exactly as the operational reading of locality requires.

(10) Aspect, Hensen, Giustina — experimental Bell-test confirmation (1982–2015, 2022 Nobel). Aspect (Aspect, Dalibard, & Roger, 1982) performed the first decisive experimental Bell test, with time-varying analyzers that closed the locality loophole. Hensen with the Delft team (Hensen et al., 2015) and Giustina with the Vienna team (Giustina et al., 2015) closed the remaining loopholes (detection efficiency, fast random setting choice) in 2015 with loophole-free experiments. The 2022 Nobel Prize to Aspect, Clauser, and Zeilinger recognized this entire chain. These experiments are not merely tests of quantum mechanics; they are the operational foundation on which any constitution including AX-1 LC rests.

(11) Bombelli–Lee–Meyer–Sorkin — causality as the discrete primitive of spacetime (1987). Bombelli, Lee, Meyer, and Sorkin (Bombelli et al., 1987) proposed that spacetime *is* a partially ordered set whose order relation *is* the causal structure. This is the most aggressive realization of the constitutional thesis that causality is a primitive of the bulk geometry rather than a derived feature of the dynamics. The causal-set program supplies the deep mathematical confirmation that AX-1 LC can be stated as a constitutional primitive without any prior commitment to continuous spacetime.

(12) Open systems and stochastic thermodynamics — the operational forward-time arrow (1970–2012). In open quantum systems and quantum information, the same causal arrow is carried forward by the forward-time CPTP-map structure of channels and instruments (Davies and Lewis, 1970, Kraus, 1971, 1983, Nielsen & Chuang, 2010, Ozawa, 1984); no admissible channel can map a future record into a past preparation. In stochastic thermodynamics, the same arrow appears as the time-asymmetry of the fluctuation theorems (Crooks, 1999, Jarzynski, 1997, Seifert, 2012). These threads supply the modern operational language in which AX-1 LC is stated: not as a metaphysical claim about hidden variables but as a structural constraint on which kernels and which channels are admissible in a registered-record physics.

Synthesis — AX-1 LC as the axiomatic distillation. Indeed, the constitutional novelty of AX-1 LC lies not in any single ingredient above but in the axiomatic move of elevating these twelve milestones — from Galileo's ship and Newton's instantaneous-action concern through Maxwell, Lorentz, Einstein, Minkowski, Wightman, Haag, Bell, Tsirelson, Aspect, Bombelli, and the open-system / stochastic-thermodynamics literature — into a single explicit clause that any candidate theory must satisfy as a precondition for admissibility. Part V of the present paper locates the AX-1-alone Stratum-1 frameworks (special relativity and classical electrodynamics) entirely within the content credited here. After all, the cleanest move a foundational document can make is to take three and a half centuries of work on cause and effect, recognize the operational invariant they all share, and write that invariant as one axiom of the constitution.

12.2 AX-2: GGEP (Geometry–Gauge Equivalence Principle)

The geometry-gauge equivalence principle of AX-2 GGEP is the axiomatic distillation of nearly two centuries of foundational work in geometry, gauge theory, and their unification. Thirteen milestones, in chronological order, supply the structural ingredients that GGEP takes as primitive.

(1) Riemann and Bianchi — the geometric foundation (1854–1902). The mathematical foundation of GGEP is the recognition that a manifold's geometric content is carried by a single closed structure. Riemann's *Habilitationsschrift* of 1854 (Riemann, 1854) introduced the intrinsically curved n-dimensional manifold and identified the metric tensor $g_{\mu\nu}$ as the carrier of geometric content. Half a century later, Bianchi proved the closure identity that bears his name (Bianchi, 1902): the Riemann curvature tensor satisfies a differential identity $\nabla_{[\mu} R_{\nu\rho]\sigma\tau} = 0$, equivalently $dR = 0$ in differential-form language. The Bianchi identity is the geometric ancestor of every closure relation that GGEP later imposes on the composite connection: every modified Bianchi identity in the string-theoretic and cohort frameworks — including the Green–Schwarz modification of 1984 and the cohort's BI-6 identity of GG-A3-BI6 (Arisaka, 2026, A3-BI6) — is a descendant of Bianchi 1902.

(2) Einstein — the equivalence principle as geometry-as-physics (1907–1916). Einstein's equivalence principle (Einstein, 1907) and his geometric formulation of gravity (Einstein, 1915, 1916) realized the physical promise that Riemann had only sketched: locally, inertial frames remove the gravitational connection at a point, while curvature persists as the invariant tidal field. General relativity is the first foundational statement of geometry-as-physics. Einstein himself credited Mach for the philosophical impulse, and credited Levi-Civita and Ricci for the absolute differential calculus that made the construction technically possible. The equivalence principle — *gravity equals inertia under a local choice of frame* — is the conceptual ancestor that AX-2 GGEP extends from gravity alone to gauge structure in general.

(3) Noether — symmetry, conservation, and the gauge structural identities (1918). Noether's 1918 paper (Noether, 1918) contains two theorems whose roles in the GGEP lineage are distinct and complementary. *Noether's first theorem*: every continuous global symmetry of an action gives rise to a conserved current, $\partial_\mu J^\mu = 0$. *Noether's second theorem*: when the symmetry is a local gauge symmetry, the conservation law is replaced by an off-shell algebraic identity among the equations of motion — the Noether identity — and the conserved current becomes redundant. Noether II is the first technical recognition that gauge symmetries are not physical symmetries but *redundancies of description*; equivalently, that the gauge connection lives on a principal bundle rather than on the base manifold. This structural fact — that gauge structure is fundamentally a bundle concept rather than a field-theoretic decoration — is exactly what AX-2 GGEP takes as primitive.

(4) Weyl — the first attempts at unification (1918, 1929). Weyl's 1918 theory (Weyl, 1918) was the first attempt to unify electromagnetism with gravity by elevating the conformal scaling of the metric to a local symmetry — a beautiful idea that turned out to be physically wrong (it predicted observable scaling effects that are not seen) but mathematically prophetic. Weyl's 1929 reformulation as a phase symmetry of the wavefunction recovered electromagnetism in the modern form $A_\mu \to A_\mu + \partial_\mu \alpha$ and introduced the word "gauge" in its current technical sense. Weyl's two attempts together established two of GGEP's three structural commitments: first, that the gauge connection A_μ is a one-form on a principal bundle; second, that the principle of *local invariance* is a candidate primitive on the same footing as the diffeomorphism invariance of GR.

(5) Ward, Takahashi, Slavnov–Taylor — Noether's gauge identities in quantum field theory (1950–1972). Ward's 1950 paper (Ward, 1950) discovered the quantum-loop expression of Noether's second theorem in QED: the Ward identity $k^\mu \Gamma_\mu(p, p+k) = e[\Sigma(p+k) - \Sigma(p)]$ relating the photon-vertex function to the electron self-energy. Takahashi (Takahashi, 1957) extended Ward's identity to its general form. Slavnov (Slavnov, 1972) and Taylor (Taylor, 1971) generalized the construction to non-Abelian gauge theory, producing the Slavnov–Taylor identities that BRST cohomology (Becchi–Rouet–Stora–Tyutin) would later cast as off-shell algebraic relations among the renormalized vertex functions. These identities are the *operational diagnostic* that the gauge bundle's geometric content registers correctly at the boundary effective-action level; they are what makes quantum gauge theory a self-consistent operational construct, and they are the bridge between AX-2 GGEP's bulk-side principle and AX-3 OGGEP's boundary-side operational dictionary. Every textbook proof that QED is renormalizable rests on the Ward–Takahashi identity; every textbook proof that the Standard Model is renormalizable rests on the Slavnov–Taylor identity. These identities are not optional decorations; they are the price of admitting GGEP into a quantum field theory.

(6) Yang–Mills — non-Abelian gauge theory (1954). Yang and Mills (Yang and Mills, 1954) extended Weyl's local-phase symmetry from the Abelian U(1) to non-Abelian Lie groups, opening the mathematical structure that the Standard Model would later inhabit. Glashow, Weinberg, Salam, and the architects of QCD made this structure physical. Throughout this period, the language of principal bundles and connections — developed by Kobayashi and Nomizu (Kobayashi & Nomizu, 1963) and codified in the modern textbook of Nakahara (Nakahara, 2003) — became the standard mathematical vocabulary for gauge theory. Yang–Mills is the moment at which "gauge theory" became a structural primitive of theoretical physics rather than a special feature of electromagnetism.

(7) Ehresmann, Wu–Yang, and Daniel–Viallet — gauge theory *is* fiber-bundle geometry (1950–1980). The structural ingredients above acquired their exact mathematical form once gauge theory was recognized as the differential geometry of fiber bundles — which is the precise modern statement of AX-2 GGEP. Ehresmann's 1950 definition of a connection on a fiber bundle (Ehresmann, 1950) supplied the object that GGEP takes as primitive: a gauge field is a *connection*, its field strength is the *curvature* of that connection, and a gauge phase is a *holonomy*.

Wu and Yang's 1975 dictionary (Wu & Yang, 1975) translated this into physics, identifying the non-integrable phase factor — the Wilson line — with bundle holonomy and exhibiting the Dirac monopole as a topologically non-trivial $U(1)$-bundle whose quantized charge is the bundle's Chern number. By 1980 the entire Standard-Model gauge group $\mathrm{SU}(3) \times \mathrm{SU}(2) \times U(1)$ was routinely written as a principal bundle over spacetime — the gauge fields as the connection, the matter fields as sections of associated bundles (Daniel & Viallet, 1980).

This is the rigorous form of geometry-gauge equivalence: "geometry equals gauge" means that gravity (the connection on the frame bundle) and the gauge forces (connections on internal bundles) are objects of one kind, related through their curvature. AX-2 GGEP adopts this established formalism in full; its own contribution is *constitutional* — to elevate the equivalence to an axiom from which the admissible bulk is *derived* — and, in the bulk-side companion (Arisaka, 2026, A2-GG6), to force the Abelian fiber into a literal non-spatial dimension while leaving the non-Abelian sector as internal bundle curvature.

(8) Dirac, Aharonov–Bohm, Berry — topology and holonomy carry physical content (1931–1984). A separate thread, running in parallel with the algebraic development of gauge theory, established that *topology and holonomy* carry physical content even where the local field strength vanishes. Dirac (Dirac, 1931) discovered that the consistency of the magnetic monopole forces the quantization of electric charge — the first hint that gauge structure is fundamentally topological. Aharonov and Bohm (Aharonov & Bohm, 1959) demonstrated experimentally that an electron interferometer threaded by a flux-carrying solenoid records a measurable phase shift even though the electron travels through a region of zero field; the holonomy of the gauge connection around the solenoid was the only carrier of the effect. Berry (Berry, 1984) discovered the geometric phase that bears his name — a topological invariant of adiabatic transport in any quantum system, generalizing the Aharonov–Bohm phase to arbitrary parameter spaces. Wilczek and Zee subsequently extended Berry's construction to non-Abelian holonomy. Together, these results established that the gauge connection is not an auxiliary mathematical convenience but a *directly observable geometric object*.

(9) Wilson — the holonomy as a non-perturbative order parameter (1974). Wilson (Wilson, 1974) introduced the Wilson loop $W(C) = \mathrm{Tr}\,\mathcal{P}\exp(\oint_C A)$ in lattice gauge theory as the non-perturbative order parameter for confinement: in the confined phase the Wilson loop obeys an area law $\langle W(C)\rangle \sim e^{-\sigma\,\mathrm{Area}(C)}$, in the deconfined phase a perimeter law. The Wilson loop is the operational gauge-invariant observable that registers the holonomy of the gauge connection around any closed curve, and it is the first construction in which the geometric content of the connection becomes a *quantitative, measurable invariant of the non-perturbative quantum theory.* Every later development of GGEP — including the cohort framework's use of the Wilson-line phase Θ_H as the hidden variable behind quantum measurement — descends from Wilson's reading of the holonomy as a physical observable.

(10) Hosotani — gauge symmetry breaking via Wilson-line holonomy on compact directions (1983, 1989). Hosotani (Hosotani, 1983, 1989) introduced the mechanism by which a gauge symmetry in a higher-dimensional theory is broken to a lower-dimensional subgroup by a non-vanishing vacuum expectation value of the Wilson line wrapping a compact direction. The Hosotani mechanism is, in retrospect, the first concrete extra-dimensional realization of GGEP: it shows that the holonomy of the gauge connection around a compact direction *is itself a dynamical field* whose vacuum value selects the low-energy gauge content. The cohort framework's use of the S^1_θ holonomy phase as the carrier of AX-3 OGGEP's hidden-variable content is a direct descendant of the Hosotani construction; we credit Hosotani as the original architect of the *compact-holonomy-as-physical-field* reading that GGEP axiomatizes.

(11) Green and Schwarz — bulk-side classical absorption of the boundary anomaly (1984). Green and Schwarz (Green and Schwarz, 1984) discovered that in 10-dimensional supersymmetric gauge theory the gauge anomaly cancels for SO(32) and $E_8 \times E_8$ via a modification of the Bianchi identity for the 3-form field strength: $dH = \mathrm{tr}(F \wedge F) - \mathrm{tr}(R \wedge R)$. In the conventional string-theoretic narrative, this is *anomaly cancellation in the 10D bulk*; in the constitutional reading developed in Part V (and in the cohort companion GG-A3-BI6 (Arisaka, 2026, A3-BI6)), it is the first concrete realization of AX-2 GGEP in the modern era — a *bulk-side classical absorption* of the closure identity descended from Bianchi 1902. The Green–Schwarz mechanism is what string theory had to write down once it had committed to a 10D bulk with extended-object dynamics; it is also what AX-2 GGEP *forces* on any admissible bulk regardless of whether the bulk contains strings. Part V's classification locates the Green–Schwarz construction at Stratum 2, $\{$AX-1, AX-2$\}$; the cohort framework's BI-6 identity (Arisaka, 2026, A3-BI6) is the analogous Bianchi closure on the six-dimensional bulk.

(12) Maldacena — AdS/CFT as GGEP on an AdS bulk (1997). Maldacena's AdS/CFT correspondence (Maldacena, 1998), together with the bulk-to-boundary dictionaries of Gubser–Klebanov–Polyakov (Gubser, Klebanov, & Polyakov, 1998) and Witten (Witten, 1998), proposed that bulk gravity on $\mathrm{AdS}_5 \times S^5$ is equivalent to boundary $\mathcal{N} = 4$ super-Yang–Mills conformal field theory on the 4D boundary. AdS/CFT is the first complete realization of a geometry-gauge unification with a *fixed bulk-to-boundary map*: every bulk supergravity field corresponds to a specific boundary gauge-invariant operator, and the correspondence is exact in the planar limit. In the constitutional reading developed in Part V, AdS/CFT is the GGEP-closed content applied to an AdS bulk — a structural theorem of AX-2 GGEP applied to the AdS solution class, not a string-theoretic novelty. What AdS/CFT lacks, to become operational in the cohort sense, is AX-3 OGGEP (the projection that produces records as opposed to a unitary equivalence) and AX-4 MSMF (the uniqueness principle that selects a single admissible bulk from the moduli space). GGEP is the axiom from which AdS/CFT descends as a structural theorem; the cohort framework adds the two further axioms that AdS/CFT alone does not provide.

(13) Synthesis — GGEP as the axiomatic distillation. Remarkably, the axiomatic content of AX-2 GGEP is located not in any single ingredient above but in a deliberate *choice of primitive*: instead of taking "metric plus separate gauge fields" as independent inputs, GGEP insists on a unified equivalence-principle statement for a single composite object, the geometry-plus-gauge connection. Each of the twelve historical milestones above contributes a structural ingredient: Bianchi the closure identity; Einstein the equivalence-principle template; Noether the bundle-redundancy reading; Weyl the local-invariance principle; Ward, Takahashi, and Slavnov–Taylor the quantum operational diagnostics; Yang–Mills the non-Abelian extension; Ehresmann, Wu–Yang, and Daniel–Viallet the fiber-bundle formalism in which a gauge field is a connection and a gauge phase a holonomy; Dirac, Aharonov–Bohm, and Berry the topological observability; Wilson the non-perturbative order parameter; Hosotani the compact-holonomy mechanism; Green–Schwarz the bulk-side classical absorption; and Maldacena the explicit bulk-to-boundary correspondence. Part V of the present paper locates each of these milestones inside the constitutional tower: Bianchi at the geometric root; Einstein at Stratum 2 specialized to gravity alone; Yang–Mills at Stratum 2 specialized to gauge alone; Green–Schwarz and AdS/CFT at Stratum 2 in the closed geometry-plus-gauge regime. GGEP is the axiom that all of them are theorems of. After all, the deepest move a foundational document can make is to take the structural content of forty years of work by the broader physics community, recognize it as a single principle, and write that principle as one axiom of a four-axiom tower.

12.3 AX-3: OGGEP (Operational/Open GGEP)

The operational/open extension of GGEP in AX-3 OGGEP is the axiomatic distillation of nearly a century of work on quantum measurement, open-system dynamics, and bulk-to-boundary projection. Fifteen chronological milestones — the longest lineage among the four axioms, reflecting the unusual depth and duration of the measurement debate — supply the structural ingredients that AX-3 OGGEP takes as primitive. Each milestone is also located in Part V's constitutional tower (**Figure 10**): the Stratum-3 OGGEP-open frameworks — the QM sibling, the thermodynamic sibling, and the black-hole sibling — all live within the operational content this Section credits.

(1) Heisenberg — matrix mechanics and the uncertainty principle (1925, 1927). Heisenberg's 1925 paper (Heisenberg, 1925) introduced matrix mechanics, the first complete formal apparatus of the new quantum theory. His 1927 uncertainty relations (Heisenberg, 1927) established that conjugate observables cannot be jointly registered with arbitrary precision; the uncertainty principle is the first operational statement that the boundary record is structurally constrained by the choice of measurement, an anticipation of the AX-3 OGGEP instrument formalism.

(2) Schrödinger and Born — wave mechanics and the probabilistic interpretation (1926). Schrödinger's wave mechanics (Schrödinger, 1926) provided the second complete formalism, equivalent to Heisenberg's by Dirac's transformation theory (Dirac, 1930). Born's probabilistic interpretation of the wavefunction (Born, 1926) introduced the Born rule $p_\alpha = |\langle\alpha|\psi\rangle|^2$ as the bridge between the bulk-side wavefunction and the boundary-side registered outcome. In AX-3 OGGEP's reading, Born's rule is not a postulate but a theorem of the operational dictionary; the AX-3 lineage credits Born for the first rigorous formulation of what the operational compiler must produce.

(3) Bohr — complementarity and the inseparability of apparatus from observation (1928). Bohr's 1928 Como/Solvay address (Bohr, 1928) introduced the complementarity principle: a quantum measurement necessarily involves an apparatus described classically, and the complementary aspects of a quantum object cannot be jointly registered. Bohr's principle is the first foundational statement that the bulk-side quantum description and the boundary-side operational record are *not the same object*. AX-3 OGGEP takes this structural fact as a primitive of the constitution rather than as an interpretational stance: the boundary is where records live, the bulk is where the closed evolution lives, and the projection between them is the operational dictionary $\mathcal{D}$.

(4) Von Neumann — the projection postulate and the cut (1932). Von Neumann's *Mathematische Grundlagen* of 1932 (von Neumann, 1932) formalized the boundary projection as a separate postulate, sitting awkwardly alongside the Schrödinger equation as the now-famous "cut." The von Neumann cut has been the seed of every measurement-problem debate since. AX-3 OGGEP dissolves the cut by promoting the projection to the constitutional level: the bulk-to-boundary functor $\mathcal{D}$ is always-on, gauge-covariant, and CPTP, and the von Neumann projection is the macroscopic limit of $\mathcal{D}$ acting on a Geometric Attractor with a record-amplification chain.

(5) Einstein–Podolsky–Rosen — the completeness debate (1935). The EPR paper (Einstein, Podolsky and Rosen, 1935) posed the completeness problem of quantum mechanics: whether the wavefunction is a complete description of physical reality or whether further hidden variables are required. In the AX-3 lineage, the EPR argument is the historical pivot at which *what gets registered as a measurement outcome* became a central foundational question. AX-3 OGGEP resolves the completeness question by recognizing that completeness is a property of the operational compiler $\mathcal{D}$, not of the bulk Hilbert space alone.

(6) Wigner — Hilbert-space irreps and Wigner's friend (1939, 1961). Wigner's 1939 paper (Wigner, 1939) classified the irreducible unitary representations of the Poincaré group, organizing particle types by mass and spin as the two Casimir invariants of the irrep. Wigner's 1961 "Wigner's friend" thought experiment (Wigner, 1961) generalized the von Neumann cut from a single observer to a chain of observers, forcing the question of where exactly the bulk-to-boundary projection takes place. AX-3 OGGEP resolves Wigner's friend by definitional fiat: the projection is the always-on bulk-to-boundary functor $\mathcal{D}$, not a process tied to any particular observer.

(7) Bell — locality and hidden variables (1964). Bell's 1964 paper (Bell, 1964) produced the inequality that made the EPR completeness debate quantitatively testable: a wide class of locally causal hidden-variable theories make predictions distinguishable from those of standard quantum mechanics. AX-3 OGGEP inherits Bell's operational reading: the boundary record is what physics speaks of, and Bell-violating correlations within the Tsirelson bound are admissible because the boundary is the bulk-to-boundary projection shadow of a bulk that remains local in higher dimension.

(8) Stinespring, Davies–Lewis, Kraus, Ozawa — the instrument formalism (1955–1984). Stinespring (Stinespring, 1955) proved that every completely positive map admits a dilation to a unitary on a larger Hilbert space — the bridge between "collapse" and "unitary evolution + tracing out the environment" that the founders had lacked. Davies and Lewis (Davies and Lewis, 1970) introduced the modern instrument formalism, in which a measurement is a CP-map-valued random-variable rather than a projection. Kraus (Kraus, 1971, 1983) gave the operator-sum representation that has become the working tool of quantum information theory; Ozawa (Ozawa, 1984) extended the instrument formalism to sequential measurement and quantum operations. These four constructions together supply the mathematical machinery that AX-3 OGGEP's operational dictionary $\mathcal{D}$ inherits as a structural primitive.

(9) GKLS and Choi–Jamiołkowski — the generators of CP semigroups (1975–1976). Gorini–Kossakowski–Sudarshan and Lindblad (Gorini et al., 1976, Lindblad, 1976) classified the generators of completely positive Markovian semigroups, producing what is now called the GKLS or Lindblad generator. Choi (Choi, 1975) characterized complete positivity via the Choi–Jamiołkowski isomorphism. The GKLS theorem is the operational backbone of AX-3 OGGEP's admissible boundary evolution: any time-translation-covariant Markovian channel consistent with locality, complete positivity, and trace preservation must be GKLS. By the late twentieth century the textbooks of Breuer–Petruccione (Breuer & Petruccione, 2002) and Nielsen–Chuang (Nielsen & Chuang, 2010) had codified all of this into a single coherent operational language.

(10) Zeh, Joos, Zurek — the decoherence program (1970–2003). Zeh (Zeh, 1970), Joos and Zeh (Joos & Zeh, 1985), and Zurek (Zurek, 1981, 2003) traced the appearance of classical-looking pointer states to the entanglement of the system with its environment; Schlosshauer (Schlosshauer, 2005) surveyed the state of the field at the turn of the century. Decoherence does not by itself solve the measurement problem — as Bell sharply noted in (Bell, 2004), it only shifts the cut to a more convenient place — but it clarifies why classical records appear in macroscopic measurements. The Caldeira–Leggett model (Caldeira & Leggett, 1983) and the Feynman–Vernon influence-functional formalism (Feynman & Vernon, 1963) provided concrete model systems within which the system-plus-environment story could be computed. In the cohort framework, decoherence and einselection are theorems of AX-3 OGGEP acting on a bulk with a boundary record-amplification chain; the decoherence program supplies the operational language in which those theorems are stated.

(11) Bekenstein and Hawking — black-hole thermodynamics (1973, 1975). Bekenstein (Bekenstein, 1973) proposed that the entropy of a black hole is proportional to its horizon area; Hawking (Hawking, 1975) derived black-hole evaporation and the Hawking temperature $T_H = \hbar c^3/(8\pi G M k_B)$. Together, these results established that a black hole *has* an operational thermodynamic description — entropy, temperature, first law — accessible to a boundary observer outside the horizon. In Part V's classification, black-hole thermodynamics is one of the three siblings of openness at Stratum 3; the Bekenstein–Hawking story is the foundational evidence that AX-3 OGGEP applies to gravitational as well as quantum systems.

(12) Davies–Fulling–Unruh — observer-dependent thermality (1976). Davies–Fulling–Unruh (Davies, Fulling & Unruh, 1976, Unruh, 1976) established that the vacuum state seen by an inertial observer appears as a thermal bath to a uniformly accelerated observer. The Unruh effect is the canonical demonstration that the operational boundary record depends on the boundary's motion — i.e., on which $\mathcal{D}$ is used — and not only on the bulk state. AX-3 OGGEP takes this dependence as structural: different boundary frames furnish different operational dictionaries, all CPTP, all gauge-covariant, all compatible with the bulk evolution.

(13) 't Hooft, Susskind, Maldacena — the holographic principle (1993–1998). 't Hooft ('t Hooft, 1993) and Susskind (Susskind, 1995) proposed the holographic principle: the information content of a region is bounded by its boundary area in Planck units. Maldacena's AdS/CFT correspondence (Maldacena, 1998), Witten's bulk-to-boundary dictionary (Witten, 1998), and the Gubser–Klebanov–Polyakov dictionary (Gubser, Klebanov, & Polyakov, 1998) made the principle concrete in a specific ten-dimensional setting. AX-3 OGGEP uses holography not as a duality between two theories but as an *operational definition of observation itself*: measurement is the bulk-to-boundary projection that produces boundary records. In Part V's classification, AdS/CFT lives at Stratum 2 as the GGEP-closed content; AX-3 OGGEP is what promotes the AdS/CFT projection from a unitary equivalence to a genuine CPTP open-system reduction.

(14) Ryu–Takayanagi and the islands formula — holographic entanglement (2006, 2020). Ryu and Takayanagi (Ryu and Takayanagi, 2006) expressed the boundary CFT's entanglement entropy as the area of a minimal surface in the bulk AdS geometry. Almheiri–Engelhardt– Marolf–Maxfield (Almheiri et al., 2019) and Penington–Shenker–Stanford–Yang (Penington et al., 2022) extended this construction to the evaporating black hole, showing that the Page curve of black-hole evaporation can be recovered from semiclassical computations by including "island" regions in the entanglement wedge. In the AX-3 lineage, Ryu–Takayanagi and the islands formula are the most direct twenty-first-century confirmation that AX-3 OGGEP is the right operational reading of the holographic principle: the boundary's operational content (entanglement entropy) is computed directly from bulk geometric data via the projection $\mathcal{D}$.

Synthesis — AX-3 OGGEP as the axiomatic distillation. The constitutional move of AX-3 OGGEP is not the introduction of any single ingredient above but the recognition that fifteen mature traditions — quantum measurement (Heisenberg, Schrödinger, Born, Bohr, von Neumann, EPR, Bell, Wigner), the open-systems formalism (Stinespring, Davies–Lewis, Kraus, Ozawa, GKLS, Choi), the decoherence program (Zeh, Joos, Zurek), and the holographic principle (Bekenstein, Hawking, Davies–Fulling– Unruh, 't Hooft, Susskind, Maldacena, Witten, Ryu–Takayanagi, Almheiri and Penington) — are all expressing one and the same structural fact: physics is what the boundary observer registers via a CPTP, gauge-covariant projection of the bulk. Part V of the present paper locates the three siblings of openness at Stratum 3 within this synthesis: the quantum-mechanics sibling with the Born rule and Bell–CHSH violation, the classical-thermodynamics sibling with the Friston free-energy principle, and the black-hole sibling with the Page curve (Page, 1993) and the islands formula — all three families of openness sitting at the same constitutional stratum because all three are operational projections of an underlying bulk evolution. After all, the deepest move a foundational document can make on the measurement problem is to recognize that ninety years of debate dissolve once the operational projection is named as a constitutional axiom rather than carried as a craft-tradition interpretation.

12.4 AX-4: MSMF (Maximum Symmetry, Minimum Freedom)

The maximum-symmetry-minimum-freedom axiom AX-4 MSMF is the axiomatic distillation of two lineages that meet, in our view, in the present constitution for the first time: the long history of *symmetry as the deep content of physical law*, and the older philosophical lineage of *minimality as the discipline of admissible explanation*. Thirteen milestones, in chronological order, supply the structural ingredients. Each milestone is also located in Part V's constitutional tower (**Figure 10**): the Stratum-4 Full-Constitution frameworks (the Standard Model with its 28 parameters collapsed to zero, and ΛCDM cosmology with $\Omega_m = 1/\pi$ forced) are the cohort realizations of the discipline that AX-4 MSMF axiomatizes.

(1) Occam — the razor as the parent of minimality (14th c.). Occam's razor (William of Occam, fourteenth century) is the philosophical ancestor of the minimum-freedom half of AX-4 MSMF: of two explanations, prefer the one that posits fewer entities. The razor is the medieval anchor of every later naturalness argument in physics, and AX-4 MSMF is the axiomatic refinement of the razor: no continuous parameter may remain unforced, no convention may masquerade as physics, no free dial that has not been earned by symmetry or topology is admissible.

(2) Galileo — the principle of relativity as the first symmetry (1632). Galileo's *Dialogo* of 1632 (Galilei, 1632) is the first explicit physical theory built on a symmetry primitive: the laws of mechanics are the same in every inertial frame. Galileo's move — writing the symmetry first, then deriving the laws — is the historical ancestor of the maximum-symmetry half of AX-4 MSMF.

(3) Newton — inertial-frame symmetry and the first law (1687). Newton's *Principia* (Newton, 1687) formalized Galileo's principle as the first law of motion: every body persists in its state of uniform motion unless acted on by a force, which is the operational statement that inertial frames are physically indistinguishable. Newton's first law is the symmetry primitive of classical mechanics; the second and third laws follow only once the first has fixed the kinematic frame.

(4) Maupertuis, Euler, Lagrange, Hamilton — the principle of least action (1744–1834). Maupertuis's 1744 principle of least action introduced the variational discipline: among admissible motions, nature selects the one that extremizes a single scalar functional. Euler and Lagrange developed the variational formalism; Hamilton (Hamilton, 1834) cast the same principle in canonical form. The variational discipline is the operational expression of the minimum-freedom half of AX-4 MSMF: among admissible trajectories, the one nature selects is the one that minimizes the action, with no continuous knob left for the modeler to adjust.

(5) Mach — the relational principle (1893). Mach's 1893 *Science of Mechanics* (Mach, 1893) formulated the relational principle: inertial frames are defined relative to the distribution of distant matter, not to an absolute background. In the AX-4 lineage, Mach's principle is the philosophical ancestor of the anti-tuning ethos: a theory is more honest when its physical content is determined by relational structure rather than by adjustable absolute parameters.

(6) Noether — symmetry and conservation (1918). Noether's celebrated 1918 paper (Noether, 1918) proved that every continuous symmetry of the action gives rise to a conservation law, and conversely. Noether's theorem is the foundational identity that *symmetry and conservation are the same thing seen from different sides*, an identity that has organized the formal structure of physics for over a century. In the AX-4 lineage, Noether's theorem is the technical anchor that makes the maximum-symmetry side of AX-4 MSMF operational rather than aesthetic: more symmetry means more conservation laws, which means more constraints on admissible kernels.

(7) Wigner — Hilbert-space irreps as particle classifications (1939). Wigner (Wigner, 1939) extended Noether's construction from the Lagrangian to the Hilbert-space level, classifying the irreducible unitary representations of the Poincaré group and using them to organize particle types themselves; what we now call "mass" and "spin" are simply the two Casimir labels of a Wigner irrep. Wigner's classification is the historical demonstration that maximal symmetry organizes the very inventory of physical objects, not just the laws governing them.

(8) Yang–Mills and the Standard Model architects — gauge symmetry primacy (1954–1974). The success of gauge symmetry in building the Standard Model (Georgi and Glashow, 1974, Glashow, 1961, Gross & Wilczek, 1973, Politzer, 1973, Salam, 1968, Weinberg, 1967, Yang and Mills, 1954) extended Wigner's organizing role from the kinematic to the dynamic side: the content of the strong, weak, and electromagnetic interactions is determined, up to coupling constants, by the choice of gauge group. The empirical lesson of seventy years of gauge theory is that nature really is profligate in symmetry: every time the search for "the right symmetry" has been pursued seriously, nature has been at least as symmetric as the ansatz allowed. Maximum symmetry is therefore not a stylistic preference but an empirically supported regularity.

(9) Wilson and the renormalization group — relevance vs. irrelevance (1971). Wilson's renormalization-group program (Wilson, 1971) introduced the distinction between relevant, marginal, and irrelevant operators along the RG flow. In the AX-4 lineage, the RG framework is the modern technical expression of the minimum-freedom discipline: only relevant and marginal operators carry low-energy content, and these are protected by symmetry or topology; irrelevant operators die out, leaving an admissibility filter that is more honest than naive parameter-counting.

(10) 't Hooft and Susskind — naturalness as the modern razor (1979–1980). 't Hooft (THooft, 1980) and Susskind (Susskind, 1979) formulated naturalness as the modern razor: a small dimensionless number that is not protected by a symmetry is suspicious and warrants an explanation. The hierarchy problem in the Higgs sector, the small QCD theta angle, and the cosmological constant all carry this signature. AX-4 MSMF is the constitutional refinement of naturalness: not just an aesthetic warning but an axiomatic filter against unforced freedom.

(11) Weinberg — the cosmological-constant problem (1989). Weinberg's 1989 review (Weinberg, 1989) cataloged the cosmological-constant problem as the sharpest single example of the minimum-freedom failure: a parameter whose observed value is $\sim 10^{120}$ orders of magnitude smaller than its naive estimate, with no symmetry protection in the Standard Model. In Part V's classification, the cosmological-constant scale $m_\Lambda \approx 6$ meV is one of the Stratum-4 numbers that the cohort framework derives from the integer OGN-5 ledger of GG-A4-Euclid (Arisaka, 2026, A4-Euclid) and GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) — the constitutional answer to the Weinberg problem.

(12) Bousso, Polchinski, Susskind, Douglas — the string landscape (2000–2007). Bousso and Polchinski (Bousso and Polchinski, 2000) estimated that the discretuum of four-form flux vacua in string theory produces of order 10^{500} admissible solutions; Susskind (Susskind, 2003) argued for an anthropic reading; Douglas (Douglas, 2003) and Polchinski (Polchinski, 2004) developed the technical apparatus. The string-landscape discussion sharpened the question: with 10^{500} or more compactifications available, is any selection principle strong enough to pick a single vacuum? In Part V's classification, the 10^{500} landscape is the diagnostic signature of GGEP-closed without AX-4 MSMF; adding AX-4 MSMF collapses the count to exactly one.

(13) Vafa — the swampland as the consistency filter (2005). Vafa's 2005 swampland proposal (Vafa, 2005) argued that not every consistent-looking low-energy effective theory can be UV-completed to a string theory; the consistent ones form the "landscape," the inconsistent ones the "swampland." In the AX-4 lineage, the swampland program is the recognition that consistency with a deeper UV structure is itself an admissibility filter; AX-4 MSMF extends this logic from the string-theoretic UV to the full four-axiom constitution.

Synthesis — AX-4 MSMF as the axiomatic distillation. Fundamentally, what AX-4 MSMF adds beyond the ingredients cataloged above is the axiomatic move of joining the two ancient lineages — maximum symmetry (Galileo, Newton, Noether, Wigner, Yang–Mills, Standard Model) and minimum freedom (Occam, Maupertuis, Mach, Wilson, 't Hooft, Susskind, Weinberg) — into a single axiomatic clause: among all candidate theories satisfying AX-1, AX-2, AX-3, Nature selects the one with maximal symmetry and minimal non-forced freedom. Part V of the present paper locates the Stratum-4 frameworks within this synthesis: the Standard Model with its 28 free continuous parameters collapsed to zero, and ΛCDM cosmology with $\Omega_m = 1/\pi$ forced from the integer OGN-5 ledger. The 10^{500}-fold collapse in admissible vacua from Stratum 2 to Stratum 4 (Part V, §33) is the constitution's signature quantitative payoff of AX-4 MSMF. After all, what makes a body of knowledge a science is not the cleverness of its calculations but the honesty of its rules; AX-4 MSMF is the rule that forbids the unforced dial.

Closing remarks on Part II

Four statements are now on the page. It is worth asking what they have in common, because read one at a time they can look like four unrelated preferences.

They are all refusals. AX-1 refuses to let an effect precede its cause. AX-2 refuses to treat geometry and gauge as separate kinds of stuff. AX-3 refuses to let observation be a primitive act outside the physics. AX-4 refuses to let a theory carry a number that nothing forced it to carry. None of the four adds an ingredient to nature. Each one takes away a freedom that theorists had been quietly enjoying.

This is the opposite of how foundational proposals usually work, and it is deliberate. The temptation, when physics gets stuck, is to add: a new field, a new dimension, a new symmetry, a new interpretation. Adding always works, which is exactly the problem — a framework that can absorb any result by adding something has stopped making contact with the world. Taking away is harder and more informative. Every freedom removed is a place the theory can now be caught.

There is a physical picture behind this that we find genuinely persuasive. Dip a wire loop in soap solution and a film forms. The film does not select its shape from a catalog; the shape is what remains once the constraints have had their say. Change the loop and the surface changes, not because it decided to, but because nothing else was available. Physics has spent a century assuming that nature is mostly catalog — that the particle masses, the coupling constants, the cosmological parameters are selections from a menu, and that our job is to measure which item was chosen. AX-4 asks whether the menu was ever there. It proposes that the constants of nature are the soap film: not chosen, but left over.

We may of course be wrong about that, and the constitution is written so that being wrong is detectable rather than absorbable. But notice that the question is now sharp enough to lose. Before AX-4 was stated as a rule, "why these constants?" was a mood. After it, the answer is either a derivation or a failure, and there is no third option.

What the four axioms do not yet supply is a working filter. They say what kind of object a theory is; they do not say which such objects survive. A theory can honor all four and still leak probability, still depend on a hand-tuned normalization, still make no statement any instrument could contradict. Part III states the seven postulates that close that gap.

Part III

The Seven Postulates

GI, UEP, AF, CP, RG, OGN, MF

Ordered Admissibility Filters for GG-Theory Theories

If the axioms are the grammar, the postulates are the proofreading. Part II said what kind of object a theory has to be. Part III says which such objects survive contact with the world.

The difference is practical. You can write a grammatically perfect sentence that is false, and you can write a theory that respects all four axioms and is still not physics — because its dynamics leak probability, or its predictions depend on a constant somebody chose by hand, or it makes no statement that any instrument could contradict. The seven postulates are seven such filters, and a candidate theory must pass all of them.

In order, and in plain terms: POS-1 GI requires that the same symmetry which holds for a single electron still hold for a mole of them, so that a bookkeeping convention chosen in the laboratory never leaks into a prediction. POS-2 UEP requires one variational engine rather than several — the principle that makes light take the fastest path should be the same one that makes a cell minimize its surprise. POS-3 AF requires that the quantum consistency conditions called anomalies cancel exactly, not approximately; a theory with a surviving anomaly is not merely inaccurate, it is incoherent. POS-4 CP requires that probabilities stay probabilities under every allowed evolution, including the messy ones where the system is coupled to a bath. POS-5 RG requires that the answer not depend on how finely you chose to look. POS-6 OGN requires that the numbers left over be integers and simple ratios rather than free decimals. And POS-7 MF requires that every central claim name, in advance, the measurement that would kill it.

That last one is the postulate we would defend most stubbornly. A filter that lets everything through is not a filter.

Each postulate appears in the same format as the axioms. The historical section tracing its lineage from the earliest recognizable anchor to the modern mathematical form — closing with the *axiomatic move* it makes, the moment at which a working practice is promoted to a stated rule — is gathered with the other six in §26, which closes this Part.

13 Overview of the seven postulates

13.1 Role of the postulates: runtime admissibility filters

Part II supplied the four axioms as the constitutional *primitives* of GG-Theory: AX-1 LC fixed the causal arrow, AX-2 GGEP defined the bulk primitive as a single composite geometric-gauge object, AX-3 OGGEP defined observation as an operational bulk-to-boundary compilation, and AX-4 MSMF closed the theory space by maximum symmetry with minimum freedom. The postulates of the present Part now serve as runtime admissibility *filters*. They answer a different question — given the axiom-level syntax, which dynamics, normalizations, and observational claims are allowed to run?

POS-1–POS-7 are house rules that every admissible theory instance must satisfy before any domain-specific modeling (particles, cosmology, chemistry, life, mind) is allowed to begin. The canonical numbering is

$$(\text{POS-1, POS-2, POS-3, POS-4, POS-5, POS-6, POS-7}) = (\text{GI, UEP, AF, CP, RG, OGN, MF}), \tag{56}$$

and we shall keep this ordering throughout. The ordering is itself part of the axiomatic content: gauge invariance is upstream of the variational principle, anomaly freedom is upstream of admissible evolution, scale covariance is upstream of normalization, and the measurement/falsifiability contract is the final filter that turns a well-posed theory into an auditable scientific claim. It is tempting to fold OGN and MF together into a single "parsimony" clause; here they are strictly separated — OGN is normalization rigidity (no continuous basis drift), MF is the registered-observable plus kill-criterion contract.

Two terms used in the closing paragraph of every POS-N subsection below deserve a brief note. By the *axiomatic move of* POS-N we mean the constitutional content that POS-N adds beyond the inherited historical apparatus cataloged in the corresponding subsection of the century-old history Section; the closing paragraph names that content explicitly and ties it to a downstream consequence. By *Stratum* N (for $N = 1, 2, 3, 4$) we mean the Nth level of the constitutional-axiom classification developed in detail in Part V; the four strata are aligned with the four axioms, each Stratum activating one more axiom (Stratum 1 = $\{\text{AX-1}\}$, Stratum 2 = $\{\text{AX-1}, \text{AX-2}\}$, Stratum 3 = $\{\text{AX-1}, \text{AX-2}, \text{AX-3}\}$, Stratum 4 = $\{\text{AX-1}, \text{AX-2}, \text{AX-3}, \text{AX-4}\}$). Each POS-N closing paragraph below identifies the *lowest* Stratum at which the corresponding postulate first becomes a non-trivial admissibility filter; several postulates re-appear at higher strata in stronger form, and the closing paragraph records that progression.

13.2 Minimal formal setting shared by all postulates

The postulates are stated so as to cover both (i) *closed microscopic* descriptions (standard quantum field theory or closed quantum mechanics), and (ii) *open operational* descriptions required by OGGEP/GDOS. We therefore fix a minimal common mathematical language.

(i) State spaces. On the operational boundary, a "state" means a normalized, positive element of a convex state space. In quantum theory this is a density operator ρ on a Hilbert space $\mathcal{H}$:

$$\rho \succeq 0, \qquad \operatorname{Tr} \rho = 1. \tag{57}$$

In classical probability, it is a distribution $p(x) \geq 0$ with $\int p(x)\, \mathrm{d}x = 1$. In both cases, the allowed states form a convex set $\mathfrak{S}$.

(ii) Operations, channels, and instruments. An operation is a linear map on states. A quantum channel is a completely positive trace-preserving (CPTP) map $\Phi : \rho \mapsto \Phi(\rho)$. A measurement is specified by an *instrument* $\{\mathcal{I}_m\}_{m\in\mathcal{M}}$: each $\mathcal{I}_m$ is CP and $\sum_m \mathcal{I}_m$ is TP. The associated POVM is $E_m = \mathcal{I}_m^*(\mathbb{I})$ and the Born rule reads $p(m) = \mathrm{Tr}(\rho E_m)$ (see §7, Eqs. (35)–(37)).

(iii) Between-intervention evolution. Between interventions, the operational state evolves by a one-parameter family of admissible maps $\{\Phi_t\}_{t\geq 0}$ with semigroup property

$$\Phi_{t+s} = \Phi_t \circ \Phi_s, \qquad \Phi_0 = \mathrm{id}, \tag{58}$$

consistent with LC (AX-1). Under mild continuity, there exists a generator $\mathcal{L}$ such that $\Phi_t = e^{t\mathcal{L}}$. In quantum Markovian limits, admissibility plus complete positivity forces the GKLS form (Eq. (40)) (Breuer & Petruccione, 2002, Gorini et al., 1976, Lindblad, 1976).

(iv) Scale and coarse-graining. A coarse-graining or renormalization step is modeled abstractly as a map RG_ℓ acting on descriptions (states, couplings, effective actions, or operational kernels). POS-RG will require that this map commute with the operational dictionary OGGEP (AX-3). In GG-6 applications, the bulk coordinate r is identified with the RG scale as

$$r = \ln\left(\frac{E_{\mathrm{GUT}}}{\mu}\right), \tag{59}$$

so that translation in r encodes a change of effective description scale.

With this shared setting in place, we are ready to investigate the seven postulates one by one. Each will be presented in the same internal format we used for the axioms: a rigorous axiomatic statement, the mathematical formulation, the first forced consequences, a worked example drawn from a familiar laboratory protocol, a Physics-Intuition Remark, the relation to the companion engines GG-6 and GDOS, and a historical background section.

14 POS-1: Gauge invariance (GI) across scales: LGI/DGI/GGI

14.1 Rigorous statement (constitutional text)

Postulate 1 (POS-1 (GI): gauge invariance across scales)**.** *All lawful descriptions must be gauge invariant/covariant in a* layered *sense:*

(GIa) LGI (Local Gauge Invariance). *For closed microscopic dynamics, the action and quantum measure are invariant under local gauge transformations.*

(GIb) DGI (Dynamical Gauge Invariance). *For open mesoscopic dynamics, the admissible evolution maps (or their generators) are equivariant under gauge transformations acting on states and on the couplings/ports that define the open system.*

(GIc) GGI (Global Gauge Invariance). *For macroscopic ledgers, globally conserved charges are invariant bookkeeping quantities when the system is enlarged to include its exchange* *environment; coarse-grained ledgers must respect these invariants.*

In particular, any operational dynamics or measurement that violates gauge covariance is inadmissible in GG-Theory.

14.2 Mathematical formulation of LGI (closed microscopic systems)

Let G be a Lie group with Lie algebra $\mathfrak{g}$ and generators T^a. Let $A = A^a_\mu T^a \, \mathrm{d}x^\mu$ be a gauge connection on spacetime M_4, with curvature

$$F = \mathrm{d}A + A \wedge A. \tag{60}$$

A local gauge transformation is a map $g : M_4 \to G$. On matter fields ψ in representation R,

$$\psi \mapsto \psi^g = R(g)\psi, \qquad A \mapsto A^g = gAg^{-1} - (\mathrm{d}g)\, g^{-1}, \qquad F \mapsto F^g = gFg^{-1}. \tag{61}$$

LGI demands invariance of the microscopic action:

$$S[\psi^g, A^g] = S[\psi, A]. \tag{62}$$

Derivation: Noether/Ward identities and the anomaly obstruction. For an infinitesimal transformation $g(x) = \exp(\alpha^a(x)T^a)$, gauge invariance implies the covariant conservation law

$$D_\mu J^{\mu a} = 0, \tag{63}$$

with D_μ the covariant derivative. At the quantum level, the generating functional $Z[A] = \int \mathcal{D}\psi \, e^{iS[\psi,A]}$ obeys Ward–Takahashi identities. A gauge anomaly corresponds to a failure of invariance of the measure/effective action, and therefore spoils these identities. POS-AF exists precisely to forbid this quantum obstruction (Adler, 1969, Bell and Jackiw, 1969, Green and Schwarz, 1984).

14.3 Mathematical formulation of DGI (open mesoscopic systems)

For an open quantum system with state ρ, DGI is the equivariance condition for the dynamical maps:

$$\Phi_t(U_g \rho U_g^\dagger) = U_g \, \Phi_t(\rho) \, U_g^\dagger, \qquad \forall g \in G, \ \forall t \geq 0, \tag{64}$$

where U_g is the unitary representation of g on $\mathcal{H}$. In Markovian regimes $\Phi_t = e^{t\mathcal{L}}$, so (64) implies generator covariance $\mathcal{L}(U_g \rho U_g^\dagger) = U_g \mathcal{L}(\rho) U_g^\dagger$.

Constraint on GKLS **generators.** Let the generator have GKLS form

$$\dot{\rho} = \mathcal{L}(\rho) = -i[H, \rho] + \sum_k \left(L_k \rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\} \right). \tag{65}$$

A sufficient (and essentially necessary) condition for covariance is:

$$U_g H U_g^\dagger = H, \tag{66}$$
$$U_g L_k U_g^\dagger = \sum_\ell v_{k\ell}(g)\, L_\ell, \tag{67}$$

where $v(g)$ is a unitary matrix acting in the space spanned by the Lindblad operators. In the Abelian case $G = U(1)$ with generator Q and $U_\alpha = e^{i\alpha Q}$, (66)–(67) reduce to

$$[H, Q] = 0, \qquad [Q, L_k] = q_k L_k, \tag{68}$$

so each dissipative channel carries a definite gauge "charge" q_k. This is the precise open-system extension of gauge invariance: *ports may exchange charge with the environment, but they must do so in a way that respects the gauge ledger.*

Pedigree note: the complex apparatus of this clause. The supporting equations of DGI are written, as everywhere on the boundary, in complex Hilbert-space language — the unitary representation U_g, the Abelian $U_\alpha = e^{i\alpha Q}$, the GKLS generator. That complex structure is boundary-side and derived, not primitive: the i of these displays is the manufactured quarter-turn of the Foundations Branch (T-P4-1/2 of Arisaka, 2026, P4-Real), and the charge decomposition $[Q, L_k] = q_k L_k$ is a complex-eigen-operator statement whose real form is recoverable by complexification of the underlying real charge rotation — the existence of that complexification being exactly T-P4-1's content. The postulate's own demand — equivariance of the admissible maps under the gauge action — is category-neutral.

14.4 Mathematical formulation of GGI (macroscopic ledgers)

If a microscopic global symmetry yields a conserved charge

$$Q^a = \int_\Sigma J^{0a}\, \mathrm{d}^3x, \tag{69}$$

then in an open system one typically has $\frac{\mathrm{d}}{\mathrm{d}t} Q^a_{\mathrm{sys}} \neq 0$ because charge flows through ports. GGI asserts that a *ledger* conservation holds when system and environment are treated together:

$$\frac{\mathrm{d}}{\mathrm{d}t}\Big(Q^a_{\mathrm{sys}} + Q^a_{\mathrm{env}}\Big) = 0, \tag{70}$$

and that any coarse-grained macroscopic description must preserve the bookkeeping of such globally invariant ledgers.

14.5 Parameter dictionary

- G : gauge group (possibly a product group) acting on microscopic fields and operational states.
- $g(x) \in G$: local gauge transformation (LGI); U_g : induced unitary representation on $\mathcal{H}$ (DGI).

- A : gauge connection 1-form; $F = \mathrm{d}A + A \wedge A$: curvature 2-form.
- $J^{\mu a}$: Noether current; Q^a : corresponding global charge.
- Φ_t : admissible dynamical map between interventions; $\mathcal{L}$: generator.
- H : effective Hamiltonian in the GKLS generator; L_k : Lindblad (jump) operators.

14.6 Worked example: $\mathrm{U}(1)_{\mathrm{em}}$ gauge invariance applied to a Lindblad master equation

The cleanest worked example of the layered GI structure is electromagnetic $\mathrm{U}(1)_{\mathrm{em}}$ gauge invariance applied to a Markovian open quantum system — say a hydrogen atom coupled to the vacuum electromagnetic field. The LGI clause says that the closed-system Lagrangian is invariant under $\psi \mapsto \mathrm{e}^{\mathrm{i}q\alpha(x)}\psi$ and $A_\mu \mapsto A_\mu - \partial_\mu\alpha$; the DGI clause now demands that the GKLS generator describing the spontaneous-emission dynamics also intertwines the $\mathrm{U}(1)_{\mathrm{em}}$ action.

Let Q denote the electric-charge operator on the system Hilbert space $\mathcal{H}$, and let $U_\alpha = \mathrm{e}^{\mathrm{i}\alpha Q}$ be the induced unitary representation. DGI requires

$$\mathcal{L}\big(U_\alpha \rho\, U_\alpha^\dagger\big) \;=\; U_\alpha\, \mathcal{L}(\rho)\, U_\alpha^\dagger \quad \text{for every } \alpha \in [0, 2\pi), \tag{71}$$

which, written for a GKLS generator $\mathcal{L}(\rho) = -\mathrm{i}[H,\rho] + \sum_k \big(L_k \rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\}\big)$, reduces in the Abelian case to the two conditions

$$[H, Q] = 0, \qquad [Q, L_k] = q_k L_k. \tag{72}$$

The first condition is gauge-invariance of the effective Hamiltonian. The second is the axiomatic content of DGI: each Lindblad jump operator L_k must carry a definite electromagnetic charge q_k, and the ports through which the hydrogen atom exchanges photons with the vacuum must respect this charge ledger. A jump operator with no definite charge would correspond to a hidden non-conservation of the $\mathrm{U}(1)_{\mathrm{em}}$ charge across the system-environment interface — and is forbidden. This is what we mean by gauge invariance of the dissipator: not only the equations of motion but also the noise channels themselves must respect the gauge ledger.

The GGI clause completes the chain. In a macroscopic description that integrates over many photons, the global charge conservation reads

$$\frac{\mathrm{d}}{\mathrm{d}t}\big(Q^{\mathrm{em}}_{\mathrm{atom}} + Q^{\mathrm{em}}_{\mathrm{field}}\big) = 0, \tag{73}$$

and any coarse-grained description that loses track of either side of this ledger is constitutionally inadmissible. Gauge invariance is not abolished by openness — it is relocated from isolated conservation to ledger-consistent exchange.

14.7 Physics intuition

Remark 5 (Physics intuition for POS-1)**.** Roughly speaking, POS-1 GI says that physics does not depend on local gauge choices, and that this independence persists across all scales. LGI is the closed-system statement: local gauge transformations leave the action invariant. DGI is the open-system extension: even in open systems, the allowed ways to couple to an environment must respect gauge structure — every jump operator carries a definite gauge charge, and the noise channels themselves intertwine the gauge action. GGI is the macroscopic ledger statement: at coarse-grained scales, conservation is not abandoned but becomes a bookkeeping constraint across system plus environment. This layered formulation is precisely the bridge that lets gauge principles export beyond particle physics into chemistry, biology, and neuroscience — openness does not remove symmetry, it relocates it from isolated conservation to ledger-consistent exchange.

14.8 Relation to GG-6 and GDOS

- **Relation to GG-6.** In GG-6 the primitive bulk structure is the composite connection $\mathcal{A}$ (§6, Eq. (3)); POS-GI requires that all observables be built from gauge-invariant curvature/holonomy data (Wilson loops, characteristic classes), and that the unified group structure be respected under the bulk–boundary dictionary (Arisaka, 2026, A2-GG6).
- **Relation to GDOS.** In GDOS the core dynamical object is an admissible open-system generator. POS-GI becomes the requirement that the GKLS generator and the measurement instrument intertwine the relevant gauge actions: this is precisely the meaning of *dynamical gauge invariance* in open mesoscopic systems (Arisaka, 2026, A5-GDOS, Breuer & Petruccione, 2002).

14.9 Further mathematical elaboration: generator covariance and Ward identities for open dynamics

In the open-system (GKLS) regime, DGI is most cleanly formulated at the generator level. Let $U(g)$ be a unitary representation of a gauge group element g on the system Hilbert space $\mathcal{H}$. DGI requires

$$\mathcal{L}\Big(U(g)\rho U(g)^\dagger\Big) = U(g)\,\mathcal{L}(\rho)\,U(g)^\dagger, \qquad \forall g \in G, \tag{74}$$

where $\mathcal{L}$ is the GKLS generator (POS-CP) of the Markov semigroup. Differentiating (74) at the identity ($g = \exp(\epsilon X)$) yields an infinitesimal Ward identity:

$$\mathcal{L}([X,\rho]) = [X, \mathcal{L}(\rho)], \tag{75}$$

which is the generator-level expression that "gauge rotations commute with time evolution."

For a GKLS generator written as

$$\mathcal{L}(\rho) = -\mathrm{i}[H,\rho] + \sum_k \left(L_k \rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\}\right), \tag{76}$$

(74) implies that $(H, \{L_k\})$ must transform covariantly: $H \mapsto UHU^\dagger$ and $L_k \mapsto \sum_j V_{kj}(g)\, UL_jU^\dagger$ for some unitary mixing $V(g)$ on the Lindblad-operator index set. Operationally, this is the open-system analog of the familiar requirement that the dynamics respect gauge redundancy: *not only the equations, but the dissipative noise channels themselves must not encode gauge-dependent physics.*

15 POS-2: Unified Extremal Principle (UEP): PLA $\Longleftrightarrow$ PLT/MEPP/FEP

15.1 Rigorous statement (constitutional text)

Postulate 2 (POS-2 (UEP): a single variational engine)**.** *There exists a* single *extremal/variational principle governing lawful dynamics.*

(UEPa) ***Bulk/closed form (PLA).*** *In closed descriptions (including the GGEP bulk), physical histories are stationary points of an action functional:* $\delta\mathcal{I}_{\mathrm{bulk}} = 0$.

(UEPb) ***Operational/open form (PLT/MEPP/FEP).*** *In open operational descriptions, the same variational structure appears, after applying the operational dictionary OGGEP and enforcing admissibility (POS-CP, POS-RG), as an extremal principle for an operational functional* $\mathcal{I}_{\mathrm{op}}$ *(least time, least free energy, or extremal entropy production, depending on representation).*

(UEPc) ***Dictionary compatibility.*** *The extremal structure commutes with the bulk→boundary compilation:*

$$\mathsf{OGGEP}(\arg\operatorname{ext} \mathcal{I}_{\mathrm{bulk}}) = \arg\operatorname{ext} \mathcal{I}_{\mathrm{op}}. \tag{77}$$

Thus GG-Theory does not postulate separate dynamical "engines" for mechanics, thermodynamics, biology, or cognition; it postulates one engine whose representations differ after openness and coarse-graining are accounted for.

15.2 PLA in closed systems: from action to equations of motion

For a mechanical system with generalized coordinates $q^i(t)$ and Lagrangian $L(q, \dot{q}, t)$,

$$\mathcal{I}_{\mathrm{mech}}[q] = \int_{t_1}^{t_2} L(q, \dot{q}, t)\, \mathrm{d}t, \tag{78}$$

stationarity $\delta\mathcal{I}_{\mathrm{mech}} = 0$ (with fixed endpoints) yields the Euler–Lagrange equations

$$\frac{\mathrm{d}}{\mathrm{d}t}\frac{\partial L}{\partial \dot{q}^i} - \frac{\partial L}{\partial q^i} = 0. \tag{79}$$

For fields $\phi^A(x)$, $\mathcal{I} = \int \mathrm{d}^d x\, \mathcal{L}(\phi, \partial\phi)$ yields

$$\partial_\mu \frac{\partial \mathcal{L}}{\partial(\partial_\mu \phi^A)} - \frac{\partial \mathcal{L}}{\partial \phi^A} = 0. \tag{80}$$

In GG-6 the bulk action is a 6D functional of the metric and the composite connection (schematically)

$$\mathcal{I}_6 = \int_{\mathcal{M}_6} \mathrm{d}^6x \sqrt{|g|} \left(\frac{1}{2\kappa^2} R - \frac{1}{4g_5^2} \mathrm{Tr}(\mathcal{F}_{MN}\mathcal{F}^{MN}) + \cdots \right) + \mathcal{I}_{\text{inflow}} + \mathcal{I}_{\partial}, \tag{81}$$

where $\mathcal{F}$ is the curvature of the composite connection $\mathcal{A}$ (§6, Eq. (4)). The details belong to the GG-6 paper (Arisaka, 2026, A2-GG6); here we emphasize that UEP demands a single bulk variational principle.

15.3 Open-system extremals: large deviations and gradient flows

This paragraph is written for readers with a background in stochastic processes and large-deviation theory. Its content is a pointer to the literature, not a step in the constitutional argument; nothing later in this paper depends on it.

A mathematically clean bridge from PLA to "thermodynamic" extremals is provided by large-deviation theory. Consider a stochastic process (Langevin form)

$$\dot{x}_t = b(x_t) + \sqrt{2\epsilon}\,\eta_t, \tag{82}$$

with white noise η_t and noise strength ϵ. As $\epsilon \to 0$, the path measure concentrates on trajectories that minimize an *action-like* functional (the Onsager–Machlup functional) (Freidlin & Wentzell, 1998, Onsager & Machlup, 1953, Touchette, 2009):

$$\mathbb{P}[x(\cdot)] \asymp \exp\left[-\frac{1}{\epsilon}\mathcal{I}_{\text{op}}[x]\right], \qquad \mathcal{I}_{\text{op}}[x] = \frac{1}{4}\int_{t_1}^{t_2} \|\dot{x} - b(x)\|^2_{D^{-1}} \mathrm{d}t + \cdots, \tag{83}$$

where D is the diffusion matrix and $\|v\|^2_{D^{-1}} = v^\top D^{-1} v$. The "most probable" path is therefore an extremal path even in a dissipative/open setting.

A particularly important case is *gradient flow*. If $b(x) = -M\nabla F(x)$ for a mobility matrix $M \succeq 0$ and a scalar functional $F(x)$ (free energy, relative entropy, or a generalized potential), then

$$\dot{x} = -M\nabla F(x) \quad \Rightarrow \quad \frac{\mathrm{d}F}{\mathrm{d}t} = -\nabla F^\top M \nabla F \le 0. \tag{84}$$

Thus the same variational structure yields a monotone descent principle on the boundary. This supplies a precise meaning for "least free energy" or "maximum dissipation" principles: they are re-expressions of the extremal structure in an open-system metric.

15.4 Why "least time" appears operationally

Fermat's principle in optics states that the physical ray extremizes the travel time $\mathcal{T} = \int n(x)\,\mathrm{d}s/c$. In operational open systems, a least-time structure can arise when the relevant cost functional includes an explicit time-to-target tradeoff, and one minimizes over final time. In GG-Theory the point is not to postulate PLT separately, but to interpret PLT-like functionals as representations of the same extremal engine once openness/retardation (LC) and admissibility (CP) are imposed.

15.5 Parameter dictionary

- $\mathcal{I}_{\rm bulk}$: bulk action functional; $\delta\mathcal{I}_{\rm bulk} = 0$ gives equations of motion.
- $\mathcal{I}_{\rm op}$: operational functional controlling admissible open dynamics; representation may be "time", "free energy", or "entropy production" depending on variables.
- $x(t)$: coarse-grained operational degrees of freedom; $b(x)$: drift; D : diffusion matrix; ϵ : noise strength.
- $F(x)$: scalar Lyapunov/ledger functional (free energy, relative entropy, generalized potential); M : mobility matrix.

15.6 Worked example: Fermat's principle as the eikonal limit of least action

A concrete instance brings out the discipline. The cleanest worked example of the unified extremal engine UEP is the derivation of Fermat's principle of least time in optics from the underlying least-action principle of electromagnetism. Fermat's principle states that a light ray traversing a medium with refractive index $n(\mathbf{x})$ extremizes the optical path length

$$\mathcal{T}[\gamma] \;=\; \int_\gamma n(\mathbf{x})\,\mathrm{d}s, \tag{85}$$

which is the geometric expression of PLT. In closed electromagnetic theory, by contrast, the wave equation for the electric field E in a slowly varying medium follows from the Maxwell action $S[A_\mu] = -\frac{1}{4}\int F^{\mu\nu}F_{\mu\nu}\,d^4x$ through PLA. The two principles look like separate dynamical engines. UEP predicts that they are not.

The bridge runs as follows. Write the wave equation in the eikonal ansatz $E(\mathbf{x},t) = A(\mathbf{x})\,\mathrm{e}^{\mathrm{i}k_0 S(\mathbf{x}) - \mathrm{i}\omega t}$, where S is a scalar phase function and $k_0 = \omega/c$ is the vacuum wavenumber. Expand in the high-frequency limit $k_0 \to \infty$. At leading order one obtains the eikonal equation

$$|\nabla S(\mathbf{x})|^2 \;=\; n^2(\mathbf{x}), \tag{86}$$

whose characteristics — the integral curves of ∇S — are precisely the geometric optical rays. Reading Eq. (86) as a Hamilton-Jacobi equation with Hamiltonian $H = c|\mathbf{p}|/n$ and applying the standard Maupertuis-Jacobi reformulation, one finds that the rays extremize exactly the time integral of Eq. (85). The Maxwell PLA in the eikonal limit *is* Fermat's PLT — the same extremal engine in two representations (Born & Wolf, 1999).

The axiomatic reading is that UEP does not merely *permit* this kind of equivalence; it *forces* it. An admissible theory cannot run two competing dynamical engines for the same physical process. Once the closed-system PLA is specified for a sector and the operational dictionary OGGEP projects to the boundary description, the boundary-side PLT, free-energy descent, or maximum-entropy production functional is forced. The companion paper (Arisaka, 2026, A5-GDOS) extends this argument to the full boundary law: gradient flow on a free-energy potential is the universal GDOS representation of the closed-system action under OGGEP, and Fermat's principle is the simplest historical instance.

15.7 Physics intuition

Remark 6 (Physics intuition for POS-2)**.** Roughly speaking, POS-2 UEP says that Nature does not run multiple dynamical engines for the same process. What appears as "straightest path" (geodesic, least action) in a closed geometric description appears as "fastest path" (Fermat) or "most efficient relaxation" (least free energy, extremal entropy production) in an open operational description. The conceptual unification is achieved by the operational dictionary OGGEP and stabilized by the admissibility constraints POS-4 CP, POS-5 RG, POS-6 OGN, and POS-7 MF. The same variational principle threads through Fermat's optics, Hamiltonian mechanics, the Maupertuis form of the action, the eikonal limit of wave optics, the gradient-flow form of the Fokker-Planck equation, and the free-energy descent of statistical mechanics — a remarkable unity that the GG-Constitution promotes from coincidence to axiomatic content.

15.8 Relation to GG-6 and GDOS

- **Relation to GG-6.** In GG-6 the bulk variational principle is written in terms of the composite connection and bulk geometry. UEP implies that geodesics, field equations, and extremal surfaces in the 6D bulk are the primitive dynamical objects (Arisaka, 2026, A2-GG6, Maldacena, 1998, Witten, 1998).
- **Relation to GDOS.** In GDOS the open-system evolution must admit a scalar "ledger" (Lyapunov functional) consistent with complete positivity and gauge invariance. UEP then postulates that open dynamics is selected by extremizing (or descending) this ledger functional in the appropriate operational metric (Arisaka, 2026, A5-GDOS, Breuer & Petruccione, 2002).

15.9 Further mathematical elaboration: from least action to gradient-flow and least free energy

A convenient bridge between PLA (bulk) and "least free energy" (boundary) is the Onsager–Machlup form of path probabilities. Consider an overdamped stochastic dynamics on a state manifold with drift $b(y) = -M\nabla F(y)$ and diffusion D:

$$\dot{y} = -M\nabla F(y) + \sqrt{2D}\,\eta(t), \tag{87}$$

where η is standard white noise. For small noise, trajectories concentrate around minimizers of an effective stochastic action (Onsager & Machlup, 1953, Seifert, 2012)

$$S_{\mathrm{OM}}[y] \approx \frac{1}{4}\int_{t_0}^{t_1} \mathrm{d}t\,\big(\dot{y} + M\nabla F\big)^{\top} D^{-1}\big(\dot{y} + M\nabla F\big) \;+\; \frac{1}{2}\int_{t_0}^{t_1} \mathrm{d}t\,\nabla\cdot(M\nabla F), \tag{88}$$

so that the *most probable* path solves, to leading order,

$$\dot{y} = -M\nabla F(y). \tag{89}$$

Equation (89) is the textbook gradient-flow law: it is literally "steepest descent" in the metric induced by M. The Lyapunov identity

$$\frac{\mathrm{d}}{\mathrm{d}t}F(y(t)) = -(\nabla F)^{\top} M(\nabla F) \leq 0 \tag{90}$$

is then an immediate consequence, and can be read as the boundary face of an extremal principle: the system follows the path that decreases F most efficiently given the mobility constraints. In this sense, "least action" persists in open systems, but the appropriate action is the large-deviation functional (88) and the appropriate potential is the GFF ledger F_{GFF}.

The PLT/FEP/MEPP language can be understood as different operational summaries of (89) and (90) under different choices of coarse-graining and cost functionals. UEP's axiomatic role is to insist that these are not unrelated principles, but different avatars of one variational engine once the operational dictionary is fixed.

16 POS-3: Anomaly freedom and cancellability by inflow (AF)

16.1 Rigorous statement (constitutional text)

Postulate 3 (POS-3 (AF): anomaly freedom via inflow)**.** *All admissible GG-Theory theories must be free of gauge, mixed gauge–gravitational, and global anomalies. If anomalies arise in an effective boundary description, they must be canceled by inflow from the bulk via a single Green–Schwarz-type mechanism, implemented as a modified Bianchi identity in the GGEP bulk.*

16.2 What "anomaly freedom" means in the constitutional reading

The conventional quantum-field-theoretic story — the one repeated in every textbook since the late 1960s — introduces "anomaly" as a boundary pathology of the quantum effective action. In a gauge theory with partition function $Z[A] = \int \mathcal{D}\psi\, e^{iS[\psi,A]}$, gauge symmetry requires $Z[A^g] = Z[A]$; a gauge anomaly means $Z[A^g] \neq Z[A]$, equivalently that the effective action $\Gamma[A] = -i \ln Z[A]$ varies as $\delta_\epsilon \Gamma[A] = \int_{M_4} \epsilon^a(x)\, \mathcal{A}^a(x)$, with the anomaly functional $\mathcal{A}^a$ computed at one loop. An uncanceled anomaly makes the boundary 4D theory inconsistent: it violates unitarity and/or current conservation at the quantum level.

Roughly speaking, this is the boundary-side report. Indeed, the constitutional reading inverts it: POS-3 AF takes the boundary quantum "anomaly" to be the AX-3 OGGEP *projection shadow* of a deeper structural identity in the bulk — a classical, topological, purely geometric identity descended from Bianchi 1902. In the bulk, the differential identity $d^2 = 0$ on the gauge-bundle curvatures forces a Bianchi-type closure $dX_4 = 0$ on every admissible four-form polynomial X_4 that the AX-2 GGEP composite connection produces. When the AX-3 boundary operation projects the bulk to its 4D slice $M_4 = \partial\mathcal{M}_6$, the bulk identity becomes the requirement that the boundary effective action respect a corresponding Ward identity for every conserved current; the boundary quantum effective action either satisfies this Ward identity — in which case the theory is admissible — or it fails to, in which case what the textbook calls "the anomaly" is precisely the boundary's measurement of its own inability to honor the upstream bulk identity. Anomaly freedom in the constitutional reading is therefore the same kind of statement as AX-1 LC: both express the conservation of a geometric current along a closed bulk manifold via a Bianchi-type identity (see the Anomaly-Freedom remark below for the full geometric statement).

16.3 Inflow as bulk-side classical absorption (modified Bianchi identity)

The Green–Schwarz construction (Green and Schwarz, 1984) is conventionally introduced as a mechanism for "canceling" boundary anomalies at the quantum loop level. In the constitutional reading it is something more honest: a bulk-side *classical* absorption of the structural identity that descends from Bianchi 1902. One introduces a 2-form B_2 with field strength $H_3 = \mathrm{d}B_2 + \cdots$ and the bulk coupling

$$\mathcal{I}_{\text{inflow}} = \int_{\mathcal{M}_6} B_2 \wedge X_4, \tag{91}$$

where X_4 is a 4-form polynomial built from gauge and gravitational curvatures. The bulk gauge variation of B_2 is absorbed by the bulk Chern–Simons descent of X_4, exactly so as to maintain the bulk classical-topological identity $dX_4 = 0$ — the closure of the four-form polynomial under the differential, which is the AX-2 GGEP-bundle expression of Bianchi 1902. The boundary OGGEP projection then sees a Ward identity that the boundary effective action is required to honor; what the standard textbook calls "cancellation of the boundary anomaly by the bulk inflow" is, in the constitutional reading, the boundary's discovery that its quantum loop merely re-measures the bulk classical identity already in force. What is absorbed at the bulk level is therefore a classical-topological fact, not a quantum loop. The mechanism nonetheless requires that H_3 obey a modified Bianchi identity

$$\mathrm{d}H_3 = \frac{1}{16\pi^2}\Big(a\ \mathrm{Tr}(F \wedge F) + b\, F_B \wedge F_B + c\ \mathrm{Tr}(R \wedge R)\Big), \tag{92}$$

with constitutionally fixed coefficients (a, b, c). In GG-6 applications, F is the $SU(5)$ curvature, F_B is the $U(1)_B$ curvature, and R is the curvature 2-form of the Levi–Civita connection. A publication basis consistent with the GG-6 stage is

$$\mathrm{d}H_3 = \frac{1}{16\pi^2}\left[\mathrm{Tr}(R \wedge R) - \mathrm{Tr}(F_{SU(5)} \wedge F_{SU(5)}) - \frac{2}{5}\, F_B \wedge F_B\right], \tag{93}$$

while alternative reciprocal conventions correspond to rescalings of the Abelian generator. POS-OGN will later forbid "basis drift" by fixing a canonical normalization in which these coefficients are minimal rational numbers.

16.4 Constraint power: anomalies as a discrete filter

Beyond consistency, anomaly cancellation is a *powerful filter* on admissible matter content and gauge structure. In the Standard Model, anomaly cancellation fixes the hypercharge assignments of fermions. In GG-6 the postulate is used as a stage-defining constraint that locks gauge and gravitational sectors in a single bulk geometry (Green and Schwarz, 1984, Weinberg, 1995).

16.5 Parameter dictionary

- $\Gamma[A]$: quantum effective action; $\delta_\epsilon\Gamma$ encodes anomalies.
- B_2 : 2-form (Green–Schwarz field); H_3 : gauge-invariant 3-form field strength.
- X_4 : 4-form polynomial in curvatures; F : gauge curvature; F_B : Abelian curvature; R : gravitational curvature.
- (a, b, c, d) : fixed rational coefficients of the four-component modified Bianchi identity (Eq. (94)); fixed by consistency and by OGN.

16.6 Worked example: the BI-6 four-component anomaly polynomial with trace-ratio lock $|a/c| = |a/d| = 5/2$

The canonical worked example of POS-3 AF is the four-component anomaly polynomial that the GG-Theory program inherits as the fingerprint of its axiomatic content. The four-factor composite gauge group $G_{\text{tot}} = \text{Spin}(1,5)\times\text{SU}(5)\times\text{U}(1)_B\times\text{U}(1)_{Qi}$ of AX-2 GGEP produces exactly four anomaly contributions in six dimensions: the gravitational $\text{tr}(R\wedge R)$, the non-Abelian $\text{tr}(F_{\text{SU}(5)}\wedge F_{\text{SU}(5)})$, the Abelian $F_B\wedge F_B$, and the Abelian $F_{Qi}\wedge F_{Qi}$. POS-3 AF demands that the total anomaly polynomial X_4 be exact, so that its descent provides a H_3 form whose modified Bianchi identity absorbs the boundary anomaly inflow exactly.

The canonical four-component coefficient vector that solves this constraint is (Arisaka, 2026, A2-GG6; Arisaka, 2026, A3-BI6)

$$X_4 \;=\; a\ \text{tr}(R\wedge R) + b\ \text{tr}(F_{\text{SU}(5)}\wedge F_{\text{SU}(5)}) + c\,F_B\wedge F_B + d\,F_{Qi}\wedge F_{Qi},$$
$$(a,b,c,d) \;=\; (1,\ -1,\ -2/5,\ -2/5). \tag{94}$$

The two ratios

$$\left|\frac{a}{c}\right| \;=\; \left|\frac{a}{d}\right| \;=\; \frac{5}{2} \tag{95}$$

are the geometry-gauge *trace-ratio lock*: a single axiomatic invariant that ties the gravitational anomaly to both Abelian anomalies through the integer 5 (which, by POS-6 OGN, is the central integer of the OGN-5 ledger). The appearance of 5/2 in Eq. (95) is by no means a coincidence: the integer 5 is forced by the SU(5) factor of G_{tot}, the 2 comes from the geometric chirality count, and the denominator 5 in the Abelian coefficients is forced by the descent structure of X_4.

The full Hopkins-Singer differential-cohomology proof that Eq. (94) is the unique solution lives in (Arisaka, 2026, A3-BI6); here it suffices to record that POS-3 AF, applied to the four-factor composite group of AX-2 GGEP, forces a single four-component anomaly polynomial with no continuous freedom. This is what we mean by anomaly cancellation as a discrete filter — it picks exactly one admissible coefficient vector out of an apparently continuous space. Figure 8 visualizes the four-component inflow and the trace-ratio lock graphically.

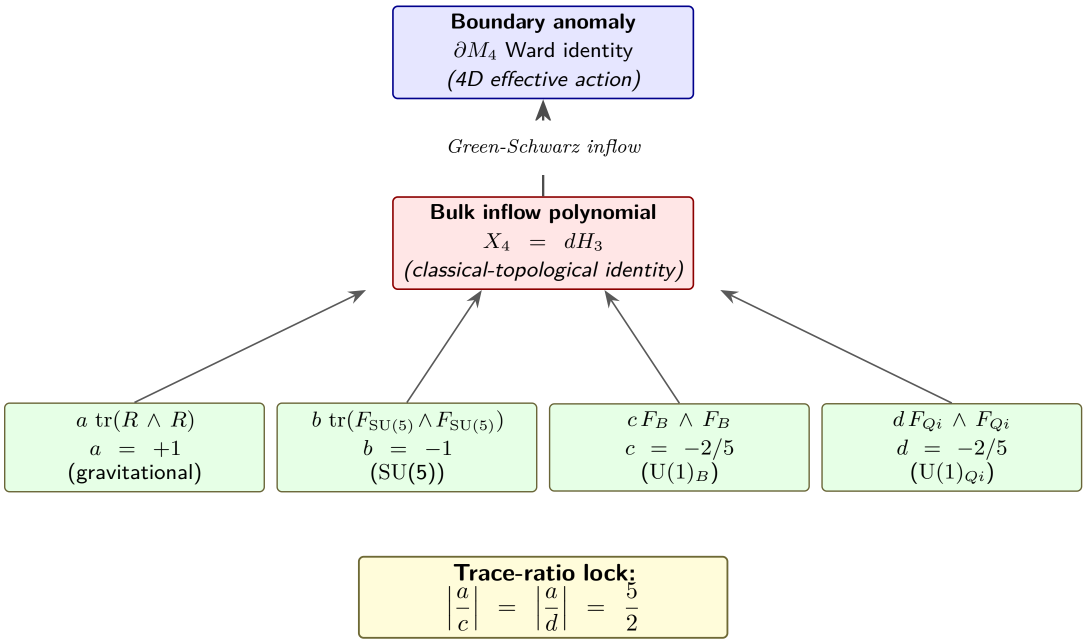

Figure 8: The four-component BI-6 bulk-side classical-topological identity, descended from Bianchi 1902. The bulk four-form polynomial $X_4 = dH_3$ (red) closes under the differential as a classical identity on the AX-2 GGEP composite connection; the four contributions — gravitational $\mathrm{tr}(R \wedge R)$, non-Abelian $\mathrm{tr}(F_{\mathrm{SU}(5)} \wedge F_{\mathrm{SU}(5)})$, $\mathrm{U}(1)_B$-Abelian $F_B \wedge F_B$, and $\mathrm{U}(1)_{Qi}$-Abelian $F_{Qi} \wedge F_{Qi}$ (green boxes) — carry the canonical coefficients $(a, b, c, d) = (1, -1, -2/5, -2/5)$. The geometry-gauge trace-ratio lock $|a/c| = |a/d| = 5/2$ (yellow) is the axiomatic fingerprint of the GG-Theory program, forced by POS-3 AF together with POS-6 OGN on the 6D bulk; the integer 5 is the central rank of the OGN-5 ledger. The boundary 4D "anomaly" (top, blue) is the AX-3 OGGEP projection shadow of this bulk identity: a boundary effective-action re-measurement of a classical-topological fact already in force in the bulk, not a quantum-loop pathology to be cured. (Illustration only; primary derivation of the trace-ratio lock is (Arisaka, 2026, A3-BI6, Theorem 8.1) and (Arisaka, 2026, A2-GG6, Theorem 4, Lemma 4.3).)

16.7 Physics intuition

Remark 7 (Physics intuition for POS-3)**.** POS-3 AF is the quantum-viability compiler. POS-1 GI provides the symmetry grammar at the classical level; POS-3 AF demands that the grammar survive quantization. Inflow cancellation can be read as a ledger balance: what appears as nonconservation in the boundary effective theory is compensated exactly by flux from the bulk. Within the GG-Constitution, this ledger interpretation is not metaphorical — it is encoded in the four-component differential-form identity of Eq. (94), and the trace-ratio lock $|a/c| = |a/d| = 5/2$ is the axiomatic fingerprint that distinguishes the GG-6 program from every other six-dimensional construction. An anomaly is not a subtle technicality to be papered over — it is a fatal admissibility failure unless it is canceled by a definite, integer-valued inflow contribution.

16.8 Relation to GG-6 and GDOS

- **Relation to GG-6.** POS-AF is stage-defining for GG-6: the bulk must contain the precise structure that allows inflow, and anomaly cancellation constrains the allowed unified gauge content (Arisaka, 2026, A2-GG6, Green and Schwarz, 1984).

- **Relation to GDOS.** POS-AF ensures that gauge covariance (POS-GI) survives the operational reduction. In open-system language, it protects Ward identities and prevents unphysical gauge nonconservation in registered observables (Breuer & Petruccione, 2002).

16.9 Further mathematical elaboration: anomaly polynomial, descent, and inflow cancellation

In $d = 4$, gauge and mixed anomalies are encoded by a 6-form anomaly polynomial I_6 whose descent generates the anomalous variation. Schematically, for a gauge connection A and curvature $F = \mathrm{d}A + A \wedge A$, one writes

$$I_6 = \mathrm{Tr}\Big(F^3\Big) + \mathrm{Tr}(F)\ \mathrm{Tr}(F^2) + \cdots, \tag{96}$$

and the descent procedure produces a 5-form Chern–Simons term ω_5 with $\mathrm{d}\omega_5 = I_6$. Under a gauge transformation, $\delta\omega_5 = \mathrm{d}\omega_4^{(1)}$, and the boundary effective action varies as $\delta W_{\mathrm{Bdy}} \sim \int_{\mathrm{Bdy}} \omega_4^{(1)}$ (the anomaly).

Inflow cancellation introduces a bulk term whose variation cancels this boundary piece. In GG-6 language, a Green–Schwarz two-form B_2 with field strength H_3 obeys a modified Bianchi identity

$$H_3 = \mathrm{d}B_2 + \omega_3, \qquad \mathrm{d}H_3 = X_4, \tag{97}$$

where X_4 is built from gauge and curvature invariants (POS-AF) and ω_3 is a Chern–Simons 3-form. Because ω_3 shifts under gauge transformations, the bulk coupling $B_2 \wedge X_4$ produces a boundary variation that cancels δW_{Bdy}. The practical message for this paper is not the detailed GG-6 construction, but the *filter*: a candidate model is inadmissible if its anomaly polynomial cannot be canceled by some allowed inflow mechanism without introducing additional non-axiomatic dials.

17 POS-4: Closure and positivity (CP)

17.1 Rigorous statement (constitutional text)

Postulate 4 (POS-4 (CP): closure and positivity)**.** *Admissible kinematics and dynamics must preserve the physical state space and close under composition.*

(CP1) ***Algebraic closure.*** *Constraint and symmetry algebras close; no inconsistent bracket relations are allowed.*

(CP2) ***State positivity.*** *States remain physical: probabilities nonnegative; quantum states remain positive semidefinite.*

(CP3) ***Dynamical admissibility.*** *Operational evolution is positivity-preserving and normalization-preserving. In quantum theory it is* CPTP*; in continuous-time Markovian limits it is generated by a* GKLS *operator.*

(CP4) Spectrum positivity. *No negative-norm/ghost degrees of freedom; physical spectra are bounded consistently.*

17.2 Complete positivity and the Kraus/Choi/Stinespring structure

A linear map Φ is positive if $\rho \succeq 0 \Rightarrow \Phi(\rho) \succeq 0$. It is *completely positive* if $\Phi \otimes \mathrm{id}_n$ is positive for all n. Complete positivity is required because an open system may be entangled with unobserved ancillas. The Kraus theorem states that a CPTP map has an operator-sum representation

$$\Phi(\rho) = \sum_\alpha K_\alpha \rho K_\alpha^\dagger, \qquad \sum_\alpha K_\alpha^\dagger K_\alpha = \mathbb{I} \tag{98}$$

(see Eq. (35)), and Stinespring's theorem provides a dilation to unitary evolution on a larger space (Choi, 1975, Kraus, 1983, Stinespring, 1955).

17.3 From semigroups to GKLS generators (a forced structure)

Assume $\{\Phi_t\}_{t\geq 0}$ is a strongly continuous semigroup of CPTP maps. Then the generator $\mathcal{L} = \lim_{t\downarrow 0}(\Phi_t - \mathrm{id})/t$ exists and must take GKLS form

$$\mathcal{L}(\rho) = -i[H, \rho] + \sum_k \left(L_k \rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\} \right), \tag{99}$$

with $H = H^\dagger$ and arbitrary L_k (Breuer & Petruccione, 2002, Gorini et al., 1976, Lindblad, 1976). Thus, in the presence of OGGEP (which defines between-intervention evolution) and LC (which fixes causal forward composition), POS-CP makes the Lindblad cone a constitutional admissibility domain, not an approximation.

Custody note: where these theorems live. Complete positivity, the Choi characterization, the Stinespring dilation, and the GKLS classification are theorems of *complex* operator algebras (Choi, 1975, Gorini et al., 1976, Lindblad, 1976, Stinespring, 1955). POS-4 is a boundary-side postulate, and it operates downstream of the manufactured i: the complex Hilbert space on which its channels act is the derived output of the Foundations Branch (T-P4-1/2/3 of Arisaka, 2026, P4-Real), so invoking complex-analytic machinery here is lawful — the boundary is where that machinery's premises hold. The bulk never runs GKLS: bulk evolution is closed and real, and no realification of the CPTP apparatus is attempted or needed. The division of labor is exact — real bulk, derived boundary i, complex boundary theorems consumed where they are theorems.

17.4 Classical analogue: Markov generators and positivity of diffusion

In classical open dynamics, admissibility often amounts to positivity of the transition kernel. For diffusions, a Fokker–Planck equation

$$\partial_t p = -\nabla \cdot (bp) + \nabla \cdot (D\nabla p) \tag{100}$$

preserves positivity provided $D \succeq 0$ and suitable boundary conditions hold. This classical positivity is the analogue of quantum complete positivity.

17.5 Parameter dictionary

- Φ : operational evolution map (channel); CPTP in quantum theory.
- K_α : Kraus operators; $J(\Phi)$: Choi matrix encoding complete positivity (Choi, 1975).
- $\{\Phi_t\}$: semigroup of channels; $\mathcal{L}$: generator; H : effective Hamiltonian; L_k : Lindblad operators.

17.6 Worked example: damped harmonic oscillator under the GKLS generator

A concrete instance brings out the discipline. The cleanest worked example of POS-4 CP is the damped harmonic oscillator under its canonical Lindblad-Gorini-Kossakowski-Sudarshan generator (Breuer & Petruccione, 2002, Gorini et al., 1976, Lindblad, 1976). Roughly speaking, the setup is as follows. A single bosonic mode with annihilation operator a and frequency ω_0 is weakly coupled to a thermal reservoir at zero temperature, so that the only environmental process is spontaneous emission at rate γ. POS-4 CP demands that the resulting state evolution be CPTP at every time, which forces the master equation into the GKLS form

$$\frac{d\rho}{dt} \;=\; -\mathrm{i}\big[\omega_0 a^\dagger a,\, \rho\big] \;+\; \gamma\left(a\rho a^\dagger - \tfrac{1}{2}\{a^\dagger a,\, \rho\}\right). \tag{101}$$

The single Lindblad operator $L = \sqrt{\gamma}\,a$ encodes the photon-emission channel; the Hamiltonian piece is the closed oscillator dynamics; the anti-commutator term is the no-jump back-reaction that preserves trace. One cannot have trace preservation without that anti-commutator — which is why POS-4 CP forces the GKLS structure rather than allowing a generic Markov master equation.

The exact solution can be read off in the $\{|n\rangle\}$ Fock basis. The diagonal populations $p_n(t) = \langle n|\rho(t)|n\rangle$ satisfy

$$\frac{dp_n}{dt} \;=\; \gamma\big[(n+1)p_{n+1} - n\,p_n\big], \tag{102}$$

which is a positivity-preserving classical Markov chain on the non-negative integers. The off-diagonal coherences decay as $\rho_{nm}(t) = \rho_{nm}(0)\,\mathrm{e}^{-\mathrm{i}\omega_0(n-m)t - \frac{\gamma}{2}(n+m)t}$. Both decays satisfy the axiomatic rule: the spectrum of $\rho(t)$ remains non-negative at every $t \geq 0$, the trace is preserved, and the asymptotic state is the vacuum $|0\rangle\langle 0|$. This is what we mean by closure and positivity as runtime admissibility filters: a master equation that violated either condition would generate negative probabilities at some finite time and thereby fail POS-4.

The axiomatic reading is exactly this: POS-4 CP is the runtime rule that turns the abstract bulk-to-boundary functor of AX-3 OGGEP into a specific algebraic class — the cone of CPTP channels and their continuous-time generators. The companion paper (Arisaka, 2026, A5-GDOS) shows that POS-4 CP, together with AX-1 LC (forward-time semigroup) and AX-3 OGGEP (operational dictionary), forces the boundary law $\mathcal{L}_{\mathsf{GDOS}}$ into precisely the GKLS class.

17.7 Physics intuition

Remark 8 (Physics intuition for POS-4)**.** POS-4 CP is the "no negative probabilities" rule elevated to the axiomatic level. It blocks the unphysical modeling moves that are otherwise tempting in complex-systems modeling — negative concentrations in chemistry, non-CP "state updates" in neuroscience, ghost instabilities in quantum-gravity perturbation theory. Together with AX-3 OGGEP, it makes measurement semantics precise: operational maps must live in the CPTP/GKLS cone, no exceptions. A theory whose predicted state can have negative eigenvalues at finite time has already failed the most basic admissibility test of an operational science — it cannot tell you the probability of any outcome.

17.8 Relation to GG-6 and GDOS

- **Relation to GG-6.** In the bulk/unification stage, closure and positivity manifest as ghost-free spectra and consistent gauge-fixing/quantization of the unified connection (Peskin and Schroeder, 1995, Weinberg, 1995).
- **Relation to GDOS.** In GDOS, POS-CP is the runtime rule that defines admissible open evolution and measurement: it forces CPTP instruments and, under continuity, Lindblad generators. This is the technical backbone of exporting quantum measurement to general open systems (Breuer & Petruccione, 2002). The downstream chain T7.1–T7.7 that derives the textbook QM postulates (Born rule, Lüders projection, decoherence, einselection, Bell–CHSH violation) from CP + OGGEP is proved in (Arisaka, 2026, A5-GDOS) and exercised at graduate-textbook depth in (Arisaka, 2026, A8-QM).

17.9 Further mathematical elaboration: closure and positivity in GKLS and classical Markov generators

In the quantum Markovian regime, "closure and positivity" becomes the statement that $\{\Phi_t\}_{t\geq 0}$ is a CPTP semigroup and therefore admits a GKLS generator:

$$\frac{\mathrm{d}}{\mathrm{d}t}\rho = \mathcal{L}(\rho) = -\mathrm{i}[H,\rho] + \sum_{\alpha,\beta} c_{\alpha\beta}\left(L_\alpha \rho L_\beta^\dagger - \frac{1}{2}\{L_\beta^\dagger L_\alpha, \rho\}\right), \qquad (c_{\alpha\beta}) \succeq 0, \tag{103}$$

where the Kossakowski matrix $(c_{\alpha\beta})$ is positive semidefinite. The positivity of $(c_{\alpha\beta})$ is the precise mathematical clause that forbids negative probabilities and guarantees complete positivity for all extensions (system + ancilla).

In the classical limit (finite-state Markov chains), the analogous statement is that probabilities $p_i(t) \geq 0$ evolve by a rate matrix W with nonnegative off-diagonal entries:

$$\dot{p}_i = \sum_{j\neq i}(W_{ij}p_j - W_{ji}p_i), \qquad W_{ij} \geq 0 \ (i \neq j), \qquad \sum_i \dot{p}_i = 0. \tag{104}$$

Equation (104) is "closure" (stays inside the simplex) and "positivity" (no negative probabilities). POS-CP asserts that any open-system effective theory used in any branch of GG-Theory must admit a representation of this kind (quantum or classical, as appropriate), so that violations of positivity/normalization are treated as axiomatic errors rather than technical glitches.

18 POS-5: RG-compatibility and scale covariance (RG)

18.1 Rigorous statement (constitutional text)

Postulate 5 (POS-5 (RG): scale coherence and RG commutation)**.** *Coarse-graining/renormalization must commute with the operational bulk→boundary dictionary. Equivalently, changing resolution ("zooming out") must not change the operational meaning of the theory.*

Formally, letting RG *denote the renormalization/coarse-graining map and* $\mathcal{D}$ *the operational dictionary,*

$$\mathcal{D} \circ \mathrm{RG} = \mathrm{RG} \circ \mathcal{D}. \tag{105}$$

In the GG-6 *stage, the bulk coordinate* r *is identified with log-energy scale by Eq.* (59)*. Dimensionless predictions are RG-invariant or belong to controlled, covariant RG flows.*

18.2 Why commutation is nontrivial

In standard practice, RG is often treated as a computational device (change of cutoff, effective action), while measurement rules are treated separately. But if observation/measurement is *defined* by OGGEP (AX-3), then it must be stable under RG: otherwise, what counts as an observable would depend on an arbitrary resolution choice, contradicting the idea that physics is objective.

18.3 Bulk–boundary reading: radial evolution as RG flow

Equation (105) becomes particularly concrete in the bulk–boundary correspondence, where radial evolution in the bulk is mapped to RG flow on the boundary. Write $T_{\Delta r}$ for bulk translation by Δr, and $R_{\Delta r}$ for boundary RG flow by the corresponding scale step. POS-RG asserts a commuting square

$$\mathcal{D} \circ T_{\Delta r} \;\cong\; R_{\Delta r} \circ \mathcal{D}. \tag{106}$$

In coupling language, for dimensionless couplings $g_i(\mu)$,

$$\mu \frac{\mathrm{d}g_i}{\mathrm{d}\mu} = \beta_i(g) \quad \Longleftrightarrow \quad \partial_r g_i = -\beta_i(g), \qquad r = \ln(E_{\mathrm{GUT}}/\mu). \tag{107}$$

Thus RG beta functions can be interpreted as radial evolution equations. This is the precise technical sense in which "scale is geometrized" in GG-6.

18.4 Scale covariance versus scale invariance

POS-RG does *not* assert that all quantities are scale invariant. Rather, it asserts that:

(RG1) physical predictions are either RG invariants (dimensionless ratios, critical exponents) or transform covariantly under RG;

(RG2) operational semantics (what is being measured and how) is preserved under coarse-graining.

This postulate is crucial for exporting to sciences where coarse-graining is unavoidable: if predictions change qualitatively when one changes measurement resolution, they are not lawful outputs of the framework.

18.5 Parameter dictionary

- RG : renormalization/coarse-graining map on the relevant description space.
- $\mathcal{D}$: operational dictionary (bulk→boundary compilation) defined by OGGEP.
- μ : boundary energy/scale parameter; E_{GUT} : unification scale; $r = \ln(E_{\text{GUT}}/\mu)$: bulk scale coordinate.
- g_i : running couplings; $\beta_i(g)$: beta functions.

18.6 Worked example: running of the QED fine-structure constant $\alpha(E)$ and scheme-independence of $\sigma(\mathrm{e^+e^-} \to \mu^+\mu^-)$

The cleanest worked example of POS-5 RG is the running of the QED fine-structure constant α with energy scale and the constitutional requirement that physical cross-sections be scheme-independent. The one-loop QED beta function gives

$$\mu \frac{d\alpha}{d\mu} \;=\; \beta_\alpha(\alpha) \;=\; \frac{2\alpha^2}{3\pi} + \mathcal{O}(\alpha^3), \tag{108}$$

whose integral, between the Thomson scale ($\alpha(0) \approx 1/137.036$) and the Z-pole ($\alpha(M_Z) \approx 1/127.9$), accounts quantitatively for the observed running.

Why is the running not a problem for the constitution? two physicists working in two schemes (say $\overline{\text{MS}}$ and on-shell) will report two different numerical values of $\alpha(\mu)$ at any given scale μ. POS-5 RG does not require that $\alpha(\mu)$ itself be scheme-independent — it requires that the operational dictionary $\mathcal{D}$ commute with coarse-graining, so that any *registered observable* produces the same number in either scheme. The axiomatic content reads

$$\mathcal{D} \circ \mathrm{RG}_\ell \;=\; \mathrm{RG}_\ell \circ \mathcal{D}, \tag{109}$$

and the cross-section $\sigma(\mathrm{e^+e^-} \to \mu^+\mu^-)(\sqrt{s})$ at any center-of-mass energy $\sqrt{s}$ is exactly such a registered observable.

The two schemes give two different $\alpha(\mu)$ functions, but they give the same $\sigma(\sqrt{s})$ to all orders in perturbation theory (Callan, 1970, Symanzik, 1970, Wilson, 1971). The scheme-difference cancels between the running coupling and the matrix-element matching coefficients — a fact that is forced, not coincidental. If it failed, the two schemes would be physically inequivalent, and the operational record at the LEP detector would depend on the calculator's bookkeeping. This is exactly the structural disaster that POS-5 RG forbids.

The bulk realization in GG-6 takes this commutation diagram and turns it into geometry. The radial coordinate r of the 6D bulk is identified with the RG flow parameter via $r = \ln(E_{\mathrm{GUT}}/\mu)$, and translation in r on the bulk implements the boundary RG flow exactly. The existence of a geometric scale coordinate is not an optional feature of the GG-Theory program — it is forced by POS-5 RG together with AX-2 GGEP, because the operational dictionary must commute with the radial flow on the bulk.

18.7 Physics intuition

Remark 9 (Physics intuition for POS-5)**.** POS-5 RG is the rule that physical truth must not depend on the resolution at which one looks at it. In the GG-Constitution this is by no means methodological — it forces the existence and interpretation of a geometric scale coordinate (the radial direction r of the 6D bulk) and demands that observation itself be scale-coherent. More precisely, the existence of a non-spatial dimension — the *scale dimension* — that plays the role of the RG flow parameter is not an optional feature of the GG-6 program but an axiomatic consequence: POS-5 forces the bulk-to-boundary functor $\mathcal{D}$ to commute with coarse-graining, and the simplest geometric realization of that commutation is a non-spatial dimension along which scale flows. In the cohort vocabulary this fifth coordinate is the *scale dimension*; the sixth coordinate S^1_θ (forced under POS-1 and POS-6) is the *gauge dimension*; together they are the two *non-spatial dimensions* of the bulk — each a scale or a phase, not a spatial *extra dimension*, the latter term being reserved for the Kaluza–Klein and string constructions with which GG-6 is contrasted.

18.8 Relation to GG-6 and GDOS

- **Relation to GG-6.** The identification of r with $\ln(E_{\mathrm{GUT}}/\mu)$ is part of the motivation for an AdS-like bulk; bulk geometry becomes a map of scale. Technical realization is discussed in (Arisaka, 2026, A2-GG6, Maldacena, 1998, Polchinski, 1995).
- **Relation to GDOS.** In GDOS, coarse-graining corresponds to changing the operational resolution of an open system. POS-RG demands that the operational dictionary (what counts as state, port, and measurement) commute with such coarse-graining. The radial-to-boundary RG bridge is developed at length in (Arisaka, 2026, A8-QM).

18.9 Further mathematical elaboration: commuting RG with observation as a commutative diagram

Let RG_ℓ denote coarse-graining by a scale parameter ℓ (e.g. integrating out modes above $\mu e^{-\ell}$), and let $\mathcal{D}$ denote the operational dictionary mapping model variables to registered observables (AX-3). POS-RG is the commutativity requirement

$$\mathcal{D} \circ \mathsf{RG}_\ell = \mathsf{RG}_\ell^{(\mathrm{obs})} \circ \mathcal{D}, \tag{110}$$

where $\mathsf{RG}_\ell^{(\mathrm{obs})}$ is the induced renormalization of estimators/response functions (calibration, bandwidth, binning, etc.). Equation (110) says: *"coarse-grain first" and "observe first" must lead to the* *same registered claim*, up to controlled, declared transformations.

In QFT this becomes the statement that dimensionless predictions are RG invariant or follow controlled flows, governed by beta functions:

$$\left(\mu\frac{\partial}{\partial\mu} + \beta^i(g)\frac{\partial}{\partial g^i} + \gamma\right)\mathcal{O}(\mu, g) = 0, \tag{111}$$

where $\mathcal{O}$ is an observable and γ denotes anomalous dimensions. In the GG-6/OGGEP vocabulary, the AdS-like radial coordinate is identified with scale,

$$r = \ln(E_{\mathrm{GUT}}/\mu), \tag{112}$$

so RG flow becomes geometric transport in r. The axiomatic content is that *scale is not an observer preference*: the dictionary and the dynamics must be compatible with the choice of resolution, otherwise "predictions" are artifacts of the microscope rather than properties of the world.

19 POS-6: Occam Gauge Normalization (OGN): rigidity and "no basis drift"

19.1 Rigorous statement (constitutional text)

Postulate 6 (POS-6 (OGN): Occam gauge normalization / minimal rational normalization)**.** *Among all basis and normalization conventions that leave POS-1–POS-5 satisfied, Nature selects a canonical normalization in which:*

(OGN1) ***Topological integrality.*** *All relevant topological integrals (fluxes, Chern/Pontryagin numbers, inflow coefficients) take integer values in the chosen units.*

(OGN2) ***Minimal rationality.*** *Any remaining rational factors are fixed in minimal coprime form shared across sectors.*

(OGN3) ***No continuous rescaling dials.*** *No arbitrary continuous normalization parameter may remain; "basis drift" is illegal.*

Equivalently: conventions are not allowed to function as hidden continuous parameters.

19.2 Why normalization is not "just convention"

In a single-sector gauge theory, one may rescale

$$A_\mu \to \lambda A_\mu, \qquad g \to g/\lambda, \tag{113}$$

leaving gA_μ invariant in covariant derivatives. This looks like a harmless convention. Yet in a multi-sector theory with Abelian factors, mixed anomalies, and topological inflow terms, such rescalings can move physical content between "couplings" and "normalization constants." Without a canonical choice, one can inadvertently *launder* parameters: a theory can appear predictive in one basis and nonpredictive in another.

POS-OGN forbids this: if a basis choice changes the integer/topological data, it is not an allowed convention.

19.3 Topological quantization and canonical units

A central mechanism is topological quantization. For an Abelian field strength F, flux quantization reads

$$\frac{1}{2\pi}\int_{\Sigma_2} F \in \mathbb{Z}, \tag{114}$$

and for non-Abelian bundles characteristic classes are integer-valued. Such conditions are invariant statements, but their manifestation as simple integers depends on normalization. OGN selects the normalization in which the corresponding lattices are *minimal* (coprime, no common factors). This is the same discipline that underlies Dirac charge quantization (Dirac, 1931) and the standard generator conventions in Lie algebras (Kobayashi & Nomizu, 1963, Nakahara, 2003).

19.4 OGN as the antidote to scheme dependence

A closely related issue is scheme dependence in renormalization and in holographic renormalization: finite local counterterms can shift definitions of quantities if not fixed by a principle. OGN asserts that the admissible scheme is the one fixed by minimal rational/integer data, so that dimensionless predictions do not drift with choice of renormalization convention.

19.5 OGN-5 integer ledger (as a stage output)

In the GG-6 stage, OGN is proposed to yield a discrete integer "ledger" (a minimal coprime set of integers shared across sectors). A canonical representative is

$$(M,N,L;J,K) = (1,3,5;7,35), \qquad J = 2N+1, \qquad K = LJ = M^2+N^2+L^2 = 35, \tag{115}$$

which is used in the GG-6 program to express several dimensionless ratios in compact rational form. In the present axiom paper we record this as an intended output of the admissibility spine; the derivation and phenomenology are presented elsewhere (Arisaka, 2026, A2-GG6).

19.6 Parameter dictionary

- λ : would-be continuous rescaling parameter (forbidden as a physical dial by POS-OGN).
- F : gauge curvature 2-form; $\int F$: flux/topological invariant (integer in canonical units).
- (a,b,c,d) : four-component coefficients of the modified Bianchi identity (92); OGN fixes their canonical rational form.
- $(M,N,L;J,K)$: example of a discrete integer ledger output in the GG-6 stage (OGN-5).

19.7 Worked example: the OGN-5 ledger and its Diophantine consistency

The canonical worked example of POS-6 OGN is the OGN-5 integer ledger that the GG-Theory program inherits from the 6D bulk (Arisaka, 2026, A2-GG6). The ledger consists of five integers

$$(M,\, N,\, L;\, J,\, K) \;=\; (1,\, 3,\, 5;\, 7,\, 35), \tag{116}$$

where M, N, L are the three primary integers attached to the three sectors of G_{tot} accessible to OGN-5; $J = 2N + 1 = 7$ is the chirality count; and $K = LJ = 35$ is the lock length that sets $r \in [0, K]$ in the canonical 6D metric $ds_6^2 = \mathrm{e}^{-2r}\eta_{\mu\nu}dx^\mu dx^\nu + dr^2 + d\theta^2$.

(Throughout, a *Diophantine consistency* is one whose admissible solutions are restricted to integers, in the tradition of Diophantus's *Arithmetica* (Diophantus, c. 3rd c.).)

The five integers are not chosen freely — they are forced by a Diophantine consistency that POS-6 OGN requires the bulk to satisfy, together with the AX-4 MSMF ordering on the primary integers and the four-component anomaly polynomial of BI-6 (full forcing proof in (Arisaka, 2026, A2-GG6)). The consistency takes the form

$$K \;=\; L\,J \;=\; M^2 + N^2 + L^2, \tag{117}$$

which one verifies directly: $L\,J = 5 \cdot 7 = 35$, and $M^2 + N^2 + L^2 = 1^2 + 3^2 + 5^2 = 1 + 9 + 25 = 35$. Strikingly, the equality of the two right-hand sides at the integer 35 is precisely the consistency condition that POS-6 OGN demands, and it is by no means a coincidence: the three-square identity $M^2 + N^2 + L^2 = K$ encodes the existence of an $\mathrm{Spin}(1,5)$-equivariant integer lattice of the right rank, while the product $K = LJ$ encodes the lock-length closure of the radial coordinate.

The axiomatic reading is that POS-6 OGN produces no continuous freedom on the bulk side — and Eq. (117) does more work than a consistency check. Read as a constraint rather than as an agreement to be admired, it *determines* the color index: substituting the closure-index clause $J = 2N+1$ gives $N = L \pm \sqrt{L - M^2}$, so integrality forces $L-1$ to be a perfect square at $M = 1$, and at $L = 5$ the two roots 3 and 7 are separated by the block embedding $N < L$, leaving $N = N_c = 3$ (Arisaka, 2026, A3-BI6, Theorem T-BI6-10.2a).

Honesty requires the exchange to be stated. Once the dual lock carries N, its two readings are *required* to agree rather than *observed* to agree, so the framework may no longer present their agreement as a free confirmation. What it buys instead is stronger: the constraint restricts the admissible block sizes to those with $L - 1$ square, $L \in \{2, 5, 10, 17, 26, \dots\}$, and $L = 5$ then arrives independently (Arisaka, 2026, A3-BI6, Theorem T-BI6-9.0). A deviation from Eq. (116) therefore produces either a mismatch in the three-square identity or a violation of the chirality count. This is what we mean by "no continuous knobs" — the entire numerical content of the bulk is fixed by five small integers, and every numerical prediction that descends to the boundary inherits its discreteness from these five integers. Figure 9 visualizes the cascade graphically.

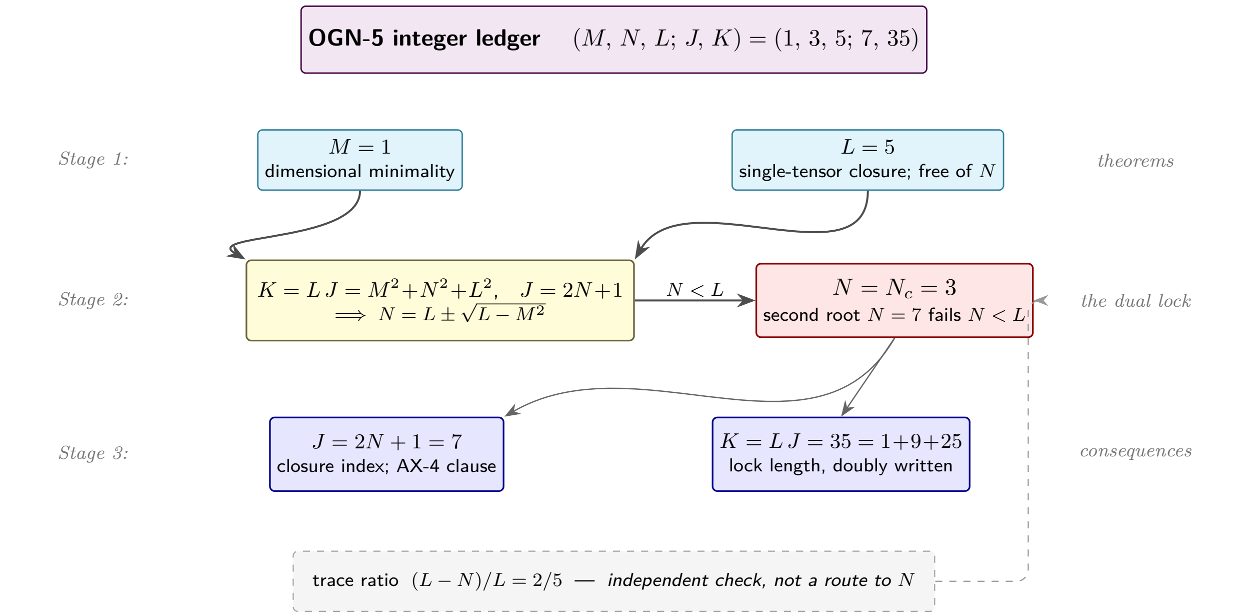

Figure 9: The OGN-5 Diophantine cascade. *Stage 1.* $M = 1$ and $L = 5$ are fixed first, and neither consumes a color count: M by dimensional minimality, L by single-tensor closure on the charged core package. *Stage 2.* The dual lock $K = LJ = M^2 + N^2 + L^2$, taken together with the closure-index clause $J = 2N + 1$, is not a consistency check performed after the fact — it is a constraint, and solving it gives $N = L \pm \sqrt{L - M^2}$. At $M = 1$ integrality forces $L - 1$ to be a perfect square; at $L = 5$ the two roots are 3 and 7, and the block embedding $N < L$ — the color block sits inside the L-dimensional defining representation — retains $N = N_c = 3$. *Stage 3.* J and K follow, the latter written two ways at once, $35 = 5 \times 7 = 1 + 9 + 25$. *The dashed box is the trace ratio,* which is computed on the 3+2 split of the defining representation and therefore cannot be used to derive the color count without assuming it; it enters as an independent check that the observed split agrees with a ledger already determined. N_c is the color index, not the generation count N_g, which is not a member of this ledger. Derivations: (Arisaka, 2026, A3-BI6, Theorems T-BI6-9.0 and T-BI6-10.2a); cascade statement (Arisaka, 2026, A2-GG6, Theorem 6).

19.8 Physics intuition

Remark 10 (Physics intuition for POS-6)**.** POS-6 OGN is the "no hidden conventions" postulate. It ensures that two researchers using different normalization conventions cannot obtain different predictions simply by drifting bases. This is the rule that turns conventions into audit-fixed integers and rationals. The value of a coupling at a reference scale is not a fact about Nature; it is a fact about a chosen convention. By forbidding continuous basis drift, POS-6 ensures that whatever survives in the GG-Theory program is a discrete consequence of the OGN-5 ledger — the integers $1, 3, 5; 7, 35$ that Eq. (116) forces and Eq. (117) verifies. Together with AX-4 MSMF, POS-6 is the constitutional clause that lets the GG-Theory program make predictions like $M_{\text{lock}} \approx 3.85\,\text{TeV}$ without a single continuous fitted parameter.

19.9 Relation to GG-6 and GDOS

- **Relation to GG-6.** OGN fixes Abelian normalizations, inflow coefficients, and the identification of discrete topological data. It is a key ingredient in the claim that GG-6 can be "parameter-closed" (no continuous free knobs beyond universal constants) once anomaly cancellation and symmetry are imposed (Arisaka, 2026, A2-GG6).

- **Relation to GDOS.** In GDOS, OGN stabilizes operational semantics across laboratories and scales: ports, couplings, and measured quantities must be normalized in a canonical way so that comparisons across experiments and domains are meaningful (Arisaka, 2026, A5-GDOS, Shannon, 1948).

19.10 Further mathematical elaboration: OGN fixes the charge lattice and removes Abelian basis drift

The simplest illustration of POS-OGN is an Abelian factor $U(1)$. If Q is the generator and g the coupling, a rescaling $Q \mapsto \lambda Q$ can be compensated by $g \mapsto g/\lambda$ so that the covariant derivative $D_\mu = \partial_\mu + \mathrm{i} g Q A_\mu$ is unchanged (the i of this covariant derivative being, as at AX-2, the boundary rendering of the circle's forced quarter-turn; T-P4-1 of Arisaka, 2026, P4-Real). This means that, without an OGN clause, a theory can acquire a continuous "normalization knob" that is not physical but can masquerade as one when combined with other sectors or with sloppy bookkeeping.

OGN fixes a canonical *charge lattice* by demanding minimal integers compatible with topology/holonomy:

$$q_i \in \mathbb{Z}, \qquad \gcd(\{q_i\}) = 1, \tag{118}$$

and by choosing canonical units for holonomy (one 2π turn on the compact circle corresponds to one integer period). The content is Occam-like but operational: once the basis is fixed, charge ratios become sharp statements and can enter falsifiers (POS-MF). In GG-6 this kind of discipline is what allows rational lock ratios (e.g. 5 : 2) to be interpreted as predictions rather than conventions.

20 POS-7: Measurement and falsifiability (MF): compile-to-observable

20.1 Rigorous statement (constitutional text)

Postulate 7 (POS-7 (MF): measurement contracts and falsifiability)**.** *Every theoretical claim in GG-Theory must compile, via the operational dictionary OGGEP, to a registered observable together with a specific instrument protocol and a pre-declared falsification (kill) criterion. Claims that cannot be compiled into such a measurement contract are not admissible as scientific statements within GG-Theory.*

20.2 Measurement is defined by OGGEP; MF adds an audit requirement

AX-3 (OGGEP) defines what "measurement" means: an instrument/POVM acting on an operational state. POS-MF adds that every theorem-level statement must include an *audit trail* to data.

Definition 8 (Measurement contract)**.** A *measurement contract* for a claim $\mathcal{C}$ is a tuple

$$\mathfrak{C}(\mathcal{C}) = (\mathcal{I}, \{E_m\}, \mathcal{S}_{\text{valid}}, \mathcal{T}, K)\,, \tag{119}$$

where: (i) $\mathcal{I} = \{\mathcal{I}_m\}$ is an instrument; (ii) $\{E_m\}$ is the associated POVM; (iii) $\mathcal{S}_{\text{valid}}$ specifies the domain of validity (state preparation, ports, calibration assumptions); (iv) $\mathcal{T}$ specifies the timescale/scale window and coarse-graining level; and (v) K is a kill criterion: a statistical or deterministic condition on observed data that would refute $\mathcal{C}$.

Since the POVM $\{E_m\}$ is determined by the instrument via $E_m = \mathcal{I}_m^*(\mathbb{I})$, the working short-form of the contract used in the worked example below and throughout the paper is the four-tuple $(\mathcal{I},\ \mathcal{S}_{\text{valid}},\ \mathcal{T},\ K)$, with $\{E_m\}$ implicit.

A typical statistical kill criterion may be stated as "reject $\mathcal{C}$ at significance level α if a test statistic $T(\text{data})$ falls outside a pre-declared acceptance region," in the spirit of standard hypothesis testing.

20.3 Parameter dictionary

- $\mathcal{I}$: instrument (family of CP maps summing to a TP map); $\{E_m\}$: associated POVM.
- $\mathcal{S}_{\text{valid}}$: explicit preparation/calibration assumptions; "what was controlled".
- $\mathcal{T}$: timescale/scale window; includes coarse-graining level relevant to POS-RG.
- K : kill criterion; may include significance level α, sample size, estimator definition, and rejection region.

20.4 Worked example: the kaxion oscillation $\Delta\nu/\nu = 1/35$ as a registered claim contract

Let us picture this concretely. One of the cleanest worked examples of a POS-7 MF claim contract is the prediction that a hypothetical kaxion field — the GG-Theory-program analogue of the QCD axion — exhibits a fractional oscillation

$$\frac{\Delta\nu}{\nu} \;=\; \frac{1}{35} \;\approx\; 0.02857\ldots \tag{120}$$

in the dark-matter sector, where the integer $35 = K = LJ$ comes from the OGN-5 lock length (Arisaka, 2026, A2-GG6; Arisaka, 2026, A10-Cosmos; Arisaka, 2026, C1-Kaxion). The Predictions-Branch paper GG-C1-Kaxion (Arisaka, 2026, C1-Kaxion) develops the explicit haloscope contract for this prediction.

The POS-7 MF claim contract for this prediction has the canonical four-tuple form $(\mathcal{I},\ \mathcal{S}_{\text{valid}},\ \mathcal{T},\ K)$, where:

- $\mathcal{I}$ — the instrument is a microwave or haloscope-style cavity tuned to the kaxion mass ($m_k \approx 8.1\,\mu$eV, equivalently 1.95 GHz), with a quantum-limited amplifier at the output and a frequency spectrum analyzer as the registered observable.

- $\mathcal{S}_{\text{valid}}$ — the preparation/calibration assumptions are: (a) the local kaxion-field amplitude tracks the standard halo dark-matter density of $0.4\,\text{GeV/cm}^3$ to within experimental dispersion; (b) the cavity Q-factor exceeds 10^4; (c) the amplifier noise temperature is at or below the standard quantum limit.

- $\mathcal{T}$ — the timescale window is the integration time of order 10^6 seconds at each tuning step, scanning over the predicted band.

- K — the kill criterion is the registered observation of any narrow spectral peak at $\Delta\nu/\nu$ that disagrees with $1/35$ at 5σ confidence over a control region of width $\geq 10\sigma_\nu$. Equivalently: a verified discovery at any $\Delta\nu/\nu \neq 1/35$ falsifies the constitution.

The axiomatic reading is exactly this: POS-7 MF does not require the theory to make every prediction precise in advance of every experimental cycle; it requires that, for every theorem that is claimed to be physical, the four-tuple $(\mathcal{I}, \mathcal{S}_{\text{valid}}, \mathcal{T}, K)$ be supplied. After all, a prediction without a registered instrument and a pre-declared kill criterion is not a scientific claim — it is a story. The kaxion contract above is one of the sharpest such contracts the GG-Theory program issues, because the integer 35 has no continuous freedom and no second-best prediction is admissible: either $\Delta\nu/\nu = 1/35$ holds or the constitution is wrong.

20.5 Physics intuition

Remark 11 (Physics intuition for POS-7)**.** POS-7 MF is the axiomatic closure of the scientific loop. A theory is not merely a mathematical structure; it is a contract between derivations and data. By forcing every theorem to compile to an $(\mathcal{I}, \mathcal{S}_{\text{valid}}, \mathcal{T}, K)$ tuple — an instrument, a calibration window, a timescale, and a pre-declared kill criterion — POS-7 blocks the most common failure mode of grand-unification programs: "explains everything, therefore predicts nothing." The kaxion oscillation contract $\Delta\nu/\nu = 1/35$ is a natural test: either Nature delivers exactly this fraction at the predicted mass, or the constitution falls. What makes a foundational document scientific rather than philosophical is the willingness to specify, in advance, exactly what would falsify it.

20.6 Relation to GG-6 and GDOS

- **Relation to GG-6.** GG-6 outputs claims about particle physics and cosmology. MF requires that these claims be stated together with explicit observables (cross sections, spectra, cosmological parameters) and refutation thresholds, not qualitative stories (Particle Data Group, 2024, Planck Collaboration, 2018).

- **Relation to GDOS.** In GDOS, MF is essential because open-system claims can otherwise drift into unfalsifiable narrative. MF forces every proposed "fingerprint" (spectral knee, scaling exponent, attractor statistic) to be tied to an explicit measurement contract.

20.7 Further mathematical elaboration: MF as pre-registered hypothesis testing

POS-MF can be expressed in the language of statistical decision theory. A theoretical claim $\mathcal{C}$ implies a distribution (or family) for a registered estimator $\widehat{\theta}$ under a specified protocol Π:

$$\mathcal{C} \;\Rightarrow\; p(\widehat{\theta}\,|\,\mathcal{C},\Pi). \tag{121}$$

A *falsifier* is then a pre-declared rejection region R_α at significance level α:

$$\text{Kill criterion:} \qquad \widehat{\theta} \in R_\alpha \implies \text{reject } \mathcal{C}. \tag{122}$$

For example, if GG-6 predicts a sharp coupling or rational ratio, the MF contract must declare the estimator, the systematic uncertainty model, and the decision rule (e.g. a likelihood-ratio test with a stated threshold). This is not a sociological preference: it is what converts a mathematical derivation into an empirically audit-ready scientific statement.

21 Inter-postulate dependency chain and why this ordering

The seven postulates compose into a directed acyclic graph rather than a flat list. A compact linear representation of the DAG is

$$\boxed{\begin{array}{c}\text{POS-1 GI} \Rightarrow \text{POS-2 UEP} \Rightarrow \text{POS-3 AF} \Rightarrow \text{POS-4 CP}\\ \Rightarrow \text{POS-5 RG} \Rightarrow \text{POS-6 OGN} \Rightarrow \text{POS-7 MF}\end{array}} \tag{123}$$

where "⇒" reads "is a prerequisite for the clean formulation of." The meaning of the chain unfolds in three groups. *First, the kinematic core:* POS-1 fixes the symmetry grammar and the admissible notion of "same physics under relabeling," POS-2 supplies the dynamical engine consistent with that grammar, and POS-3 ensures the symmetry grammar survives quantization. *Next, the operational layer:* POS-4 ensures the operational evolution remains inside the physical state space (no negative probabilities), POS-5 ensures that operational semantics and predictions do not depend on an arbitrary resolution choice, and POS-6 removes residual ambiguity in conventions, killing basis drift and parameter laundering. *Finally,* POS-7 closes the scientific loop by demanding that every statement compile to a falsifiable contract with data.

Two interlocks are especially important for exporting beyond particle physics:

I1. OGGEP+ CP ⇒ admissible open dynamics. Operational semantics plus positivity forces CPTP instruments and (under continuity) GKLS generators. This is the foundational reason GG-Theory treats open-system dynamics as axiomatic rather than "effective modeling."

I2. AF+ OGN ⇒ discrete locking. Anomaly cancellation provides integer/topological constraints, while OGN fixes their canonical normalization so they become auditable discrete data rather than scheme-dependent numbers.

22 Quick-reference equation for instruments

Before the kernel-equation collection and the summary table, we recall a single equation that is referenced repeatedly below. The full operational scaffolding — states, channels, instruments, POVMs, and the coarse-graining map RG — was fixed in §13.2. For a quantum instrument $\{\mathcal{I}_m\}_m$ (CP maps whose sum is TP) (Kraus, 1971, Nielsen & Chuang, 2010), outcome probabilities and post-measurement states are

$$p(m) = \mathrm{Tr}[\mathcal{I}_m(\rho)], \qquad \rho_m = \frac{\mathcal{I}_m(\rho)}{\mathrm{Tr}[\mathcal{I}_m(\rho)]}, \qquad \Phi(\rho) = \sum_m \mathcal{I}_m(\rho), \tag{124}$$

which is the operator-theoretic formalization of “registered measurement” used in OGGEP (AX-3) and in the row entries of Table 3 below.

23 Canonical kernel equations referenced in Table 3

For convenience, we collect the minimal “kernel equations” that are repeatedly referenced as consistency checks across the seven postulates. The intent is not to exhaust derivations (which appear in the individual postulate subsections above), but to fix *unambiguous symbols and labels* for the summary table and for later GG-6/GDOS papers.

POS-1 (GI): gauge invariance (LGI/DGI/GGI). Local gauge invariance at the action level is

$$S[A^g, \psi^g] = S[A, \psi]. \tag{125}$$

Dynamical gauge invariance in open evolution can be stated as equivariance of the channel family under the unitary representation U_g:

$$\Phi_t \circ \mathrm{Ad}_{U_g} = \mathrm{Ad}_{U_g} \circ \Phi_t, \qquad \mathrm{Ad}_{U_g}(\rho) = U_g \rho U_g^\dagger, \tag{126}$$

and the same requirement can be imposed on the generator $\mathcal{L}$ in a Markov limit. We also define a generic “ledger with ports” balance law,

$$\frac{d}{dt} F(y(t)) = J_{\mathrm{ports}}(y(t), t), \tag{127}$$

where F is a chosen GFF ledger functional and J_{ports} is the net flux through exchange channels; POS-GI requires this statement be form-invariant under gauge relabelings.

POS-2 (UEP): unified extremal principle. In closed sectors, dynamics is extremal:

$$\delta S[\phi] = 0. \tag{128}$$

In open operational regimes, a canonical boundary form is gradient/steepest-descent flow with mobility $M \succeq 0$,

$$\dot{y} = -M(y)\,\nabla F(y), \tag{129}$$

which implies a Lyapunov monotonicity (free-energy decrease) when M is positive:

$$\frac{dF}{dt} \leq 0. \tag{130}$$

For fluctuations and rare events, a large-deviation functional provides the operational extremal principle:

$$\mathbb{P}[y(\cdot)] \asymp e^{-I[y]}, \qquad I[y] = \int L(y, \dot{y})\,dt. \tag{131}$$

POS-3 (AF): anomaly freedom / cancellability by inflow. At the quantum level, a gauge variation of the effective action has the schematic form

$$\delta_\alpha \Gamma = \int \alpha\,\mathcal{A}, \tag{132}$$

and admissibility requires cancellation, possibly by inflow via a Green–Schwarz term

$$S_{\rm GS} = \int B_2 \wedge X_4, \tag{133}$$

with modified Bianchi identity

$$dH_3 = X_4. \tag{134}$$

In the GG-6 context we parameterize the admissible GS-modified BI-6 identity by the canonical four-component coefficient vector (Arisaka, 2026, A2-GG6; Arisaka, 2026, A3-BI6)

$$\begin{aligned} dH_3 \;=\; a\,\mathrm{tr}(R \wedge R) + b\,\mathrm{tr}(F_{\rm SU(5)} \wedge F_{\rm SU(5)}) + c\,F_B \wedge F_B + d\,F_{Qi} \wedge F_{Qi}, \\ (a, b, c, d) = (1,\,-1,\,-2/5,\,-2/5), \end{aligned} \tag{135}$$

where R is the bulk Lorentz curvature two-form (in the $\mathrm{Spin}(1,5)$ factor of $G_{\rm tot}$), $F_{\rm SU(5)}$ is the unified non-Abelian gauge curvature, F_B the $\mathrm{U}(1)_B$ field strength, and F_{Qi} the $\mathrm{U}(1)_{Qi}$ field strength. The geometry-gauge trace-ratio lock $|a/c| = |a/d| = 5/2$ is the axiomatic signature of BI-6 and is forced by POS-AF together with POS-OGN; its differential-cohomology proof is given in (Arisaka, 2026, A3-BI6).

POS-4 (CP): closure and positivity. Quantum operational evolution must be completely positive and trace preserving, i.e. admit a Kraus form

$$\Phi(\rho) = \sum_k K_k \rho K_k^\dagger, \qquad \sum_k K_k^\dagger K_k = \mathbb{I}, \tag{136}$$

and in a Markov limit the generator must be of GKLS form

$$\dot{\rho} = \mathcal{L}(\rho) = -i[H, \rho] + \sum_a \left(L_a \rho L_a^\dagger - \frac{1}{2}\{L_a^\dagger L_a, \rho\} \right). \tag{137}$$

In classical mesoscopic limits, positivity is preserved by Fokker–Planck generators such as

$$\partial_t p = -\nabla \cdot (bp) + \frac{1}{2}\nabla \cdot (D\, \nabla p). \tag{138}$$

POS-5 (RG): RG-compatibility and scale covariance. Operational semantics must commute with coarse-graining:

$$\mathcal{D} \circ \mathsf{RG} = \mathsf{RG} \circ \mathcal{D}, \tag{139}$$

and couplings flow by beta functions in a chosen scheme,

$$\mu \frac{dg_i}{d\mu} = \beta_i(g). \tag{140}$$

In the 6D bulk used by GG-6 (in the natural GG-6 units with no continuous parameters), the scale-covariant metric takes the canonical form (Arisaka, 2026, A2-GG6)

$$ds_6^2 \;=\; e^{-2r}\, \eta_{\mu\nu}\, dx^\mu dx^\nu + dr^2 + d\theta^2, \qquad r \in [0, K], \quad \theta \in [0, 2\pi), \tag{141}$$

where $K = 35$ is the integer lock-length (a consequence of the OGN-5 ledger; see Eq. (143)), the radial coordinate r implements RG evolution along the bulk, and the compact θ circle supplies the U(1) holonomy used in OGGEP. Translation in r commutes with the operational dictionary, in agreement with POS-RG.

POS-6 (OGN): Occam gauge normalization. Topological/quantization conditions fix discrete normalizations, e.g.

$$\frac{1}{2\pi}\int_{\Sigma_2} F \in \mathbb{Z}, \tag{142}$$

and GG-6 uses the "frozen" integer data

$$(M, N, L; J, K) = (1, 3, 5; 7, 35), \tag{143}$$

as a canonical minimal-rational normalization (no continuous rescaling dials).

POS-7 (MF): measurement and falsifiability. A measurement is an instrument $\{\mathcal{I}_m\}_m$ whose sum is a channel,

$$\Phi(\rho) = \sum_m \mathcal{I}_m(\rho), \tag{144}$$

with induced POVM elements $E_m = \mathcal{I}_m^*(\mathbb{I})$ and Born probabilities

$$p(m) = \mathrm{Tr}(\rho E_m). \tag{145}$$

MF requires that each theorem compile to a pre-declared contract (protocol, estimator, prediction, kill rule), schematically

$$(\mathcal{I}, O, \mathbb{P}_\theta, K). \tag{146}$$

24 Comprehensive summary table for POS-1–POS-7

Table 3: Postulates summary (POS-1–POS-7). Ordered admissibility filters with axiomatic content, canonical equations/checks, GG-6/GDOS bridges, and falsifiability handles. Read this table as the "runtime checklist" for any candidate model instance: a theory is not admitted unless each row can be satisfied without hidden dials.

POS	Constitutional statement (rigorous)	Mathematical kernel	Bridge to GG-6 / GDOS	Falsifiability handle
POS-1	Layered gauge invariance: LGI (action), DGI (generator equivariance), GGI (global ledgers).	$S[A^g, \psi^g] = S[A, \psi]$ (125); $\Phi_t \circ \mathrm{Ad}_{U_g} = \mathrm{Ad}_{U_g} \circ \Phi_t$ (126); ledger continuity (127).	Locks bulk gauge content and boundary ports; makes open-system laws representation-independent.	Gauge/basis changes must not alter registered predictions; illegal if they do.
POS-2	One variational engine: PLA in closed sectors projects to PLT/FEP/MEPP in open operational sectors.	$\delta S = 0$ (128); gradient flow (129); $dF/dt \le 0$ (130); path LD action (131).	Bulk geodesics/extremals (GG-6) compile to boundary optimal control/relaxation (GDOS).	Compare predicted extremal paths, relaxation laws, and time-to-target scaling to data.
POS-3	Quantum consistency: all anomalies cancel, possibly by inflow (Green–Schwarz) with a fixed Bianchi identity.	$\delta\Gamma = \int \alpha \mathcal{A}$ (132); $S_{\mathrm{GS}} = \int B_2 \wedge X_4$ (133); $dH_3 = X_4$ (134).	Forces discrete charge/representation data and locks Abelian sectors (GG-6); stabilizes ledger symmetries in GDOS.	If any required symmetry is anomalous/uncancellable, model is rejected.
POS-4	Physicality: algebras close; states remain positive; open evolutions are CPTP; Markov limits are GKSL.	Kraus form (136); GKSL (137); classical positivity (138).	Ensures bulk/boundary descriptions produce valid probabilities; fixes GDOS runtime class.	Look for negative probabilities/ghosts or non-CP evolution; these falsify admissibility.
POS-5	Scale coherence: coarse-graining commutes with observation; radial coordinate is RG scale.	$\mathcal{D} \circ \mathsf{RG} = \mathsf{RG} \circ \mathcal{D}$ (139); $\mu dg/d\mu = \beta(g)$ (140); scale-profile metric (141).	Identifies r with log energy in GG-6; constrains GDOS coarse-graining dependence.	Predictions must be RG invariant (dimensionless) or have controlled flows; otherwise illegal.
POS-6	No basis/scheme drift: canonical minimal integer/rational normalization across sectors.	Flux quantization (142); lattice primitivity; frozen integers (143).	Converts inflow/locking into sharp rational predictions (GG-6) and prevents unit drift in GDOS.	If "predictions" change under legal re-normalizations, model violates OGN.

(continued)

POS	Constitutional statement (rigorous)	Mathematical kernel	Bridge to GG-6 / GDOS	Falsifiability handle
POS-7	Every claim compiles to an operational test with protocol + kill criterion.	Instrument/POVM (144)–(145); compile tuple (146).	Enforces instrument-level semantics of OGGEP and makes GG-6/GDOS outputs scientifically auditable.	A pre-declared kill criterion exists for every theorem; otherwise claim is inadmissible.

25 The reality register of the postulates

One further audit closes Part III. The bulk clauses of this constitution are stated over the reals, and the boundary's imaginary unit is derived (T-P4-1/2/3 of Arisaka, 2026, P4-Real; constitutional pricing in L-Constitution-1, §8.5, candidate grade). It is therefore a fair — and auditable — question where, if anywhere, each postulate touches complex structure. Table 4 answers it postulate by postulate.

Table 4: The reality register of the postulates. For each of POS-1–POS-7: where complex structure appears in its statement or supporting apparatus, on which side of the bulk/boundary divide it lives, and which result owns it. POS-2, POS-3, and POS-5 are clean or bulk-real; POS-1 and POS-6 touch complex structure only in boundary rendering; POS-4 consumes complex-algebra theorems lawfully, downstream of the derived i; POS-7 inherits POS-4's apparatus.

Postulate	Where complex structure appears	Side	Owning result
POS-1 (GI)	In the supporting apparatus only: U_g, $U_\alpha = e^{i\alpha Q}$, GKLS covariance, and the charge decomposition $[Q, L_k] = q_k L_k$ (a complex-eigen-operator statement, real-form recoverable).	Boundary; derived	T-P4-1/2 (pedigree note, §14)
POS-2 (UEP)	Absent: action principles, gradient flows, ledger monotones, and large-deviation functionals are real-valued throughout.	— (clean)	Clean on inspection
POS-3 (AF)	Absent from the postulate's own data: the anomaly polynomial and the inflow term are real characteristic classes; the postulate itself states the inversion — the boundary quantum "anomaly" is the OGGEP projection shadow of a classical, topological, purely geometric bulk identity.	Bulk; real	POS-3's own statement (§16); GG-A3-BI6 (Arisaka, 2026, A3-BI6)
POS-4 (CP)	Constitutively: complete positivity, Choi, Stinespring, and GKLS are theorems of complex operator algebras, consumed as such downstream of the derived i; the bulk never runs GKLS.	Boundary; derived	Custody note (§17); T-P4-1/2/3
POS-5 (RG)	Absent: coarse-graining maps, beta functions, and the radial-scale identification are real.	— (clean)	Clean on inspection
POS-6 (OGN)	In the rendering only: the holonomy normalization reads $e^{i\theta}$ on the boundary; the constitutional object is the circle itself.	Boundary rendering	T-P4-1 (bridging sentence, §6)
POS-7 (MF)	By inheritance: instruments and POVMs act on POS-4's boundary Hilbert space; no complex input of its own.	Boundary; inherited	POS-4's custody note; T-P4-1/2/3

The certificate this register issues is short enough to quote: *every i in this document is either boundary-side and derived, or absent.* No clause of the constitution instantiates a complex primitive; where the complex apparatus is consumed (POS-4, and POS-7 through it), it is consumed on the boundary, downstream of the derived quarter-turn, which is where its premises hold.

26 Century-old history of the seven postulates

The postulates have the longer pedigree of the two lists. Gauge invariance, least action, anomaly cancellation, complete positivity, the renormalization group, normalization conventions, and the demand that a claim be measurable were each worked out by a different community for a different reason, over a century, and none of them was written as an admissibility filter at the time. This Section collects that history, postulate by postulate.

26.1 POS-1: Gauge invariance (GI) across scales: LGI/DGI/GGI

1. Faraday and Maxwell — 1845-1865. The historical seed of gauge invariance is Faraday's intuition of "tubes of force" as physical objects in space (Faraday, 1845), an intuition the young Faraday already used in 1845 to predict and observe the rotation of light polarization by a magnetic field — the first experimental hint that the electromagnetic potential carries more physical content than the local field strengths reveal. The mathematical synthesis came twenty years later in Maxwell's *Treatise on Electricity and Magnetism* (Maxwell, 1865). Maxwell did not yet have the modern terminology, but his unified equations contain the key fact: introducing the four-potential A_μ through $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$ leaves the freedom $A_\mu \to A_\mu + \partial_\mu \alpha$ without altering any physical observable. This is the first concrete instance of what we now call a local gauge transformation, and it has been the prototype of every subsequent gauge theory. Lorenz's 1867 paper (Lorenz, 1867) demonstrated that this freedom could be partially fixed by a covariant condition ($\partial^\mu A_\mu = 0$) without disturbing observables — the first technical instance of gauge fixing.

2. Hilbert and Noether — 1915-1918. The second pillar emerged from Hilbert and Noether's joint work on the variational structure of general relativity. Hilbert's 1915 derivation of the gravitational field equations from the Einstein-Hilbert action (Hilbert, 1915) demonstrated that general covariance is itself a gauge symmetry of the variational principle, and this in turn motivated Noether's celebrated 1918 paper (Noether, 1918). Noether proved that every continuous global symmetry of the action implies a conservation law (the first theorem), and — critically for the constitutional reading of POS-1 GI — that every *local* gauge symmetry forces the corresponding current to be conserved as a Bianchi-type identity at the level of the field equations themselves (the second theorem). Noether's two theorems are the structural reason electric charge is conserved in QED, color charge in QCD, and the energy-momentum tensor is divergence-free in general relativity. In our view Noether's theorem is the most important single mathematical fact in the history of theoretical physics; the entire axiomatic architecture of the GG-Theory program rests on its consequences.

3. Weyl's gauge principle — 1918 / 1929. Hermann Weyl gave the principle its modern name and modern form. Weyl's 1918 attempt at a unified field theory (Weyl, 1918) promoted a local conformal rescaling of the metric to a symmetry and coined the term *Eichinvarianz* — "gauge invariance." His specific physical proposal turned out to be empirically wrong (the predicted observable scaling effects are not seen), but the conceptual template was permanent. Weyl's 1929 reformulation, in which the local rescaling was replaced by a local phase rotation of the quantum wavefunction $\psi \to e^{i\alpha(x)}\psi$, identified the electromagnetic potential as the connection on a $U(1)$ principal bundle and made gauge invariance the foundation of quantum electrodynamics. This is the historical moment at which gauge theory became *intrinsically quantum*: a symmetry not of fields alone but of phases attached to fields.

4. Kaluza-Klein: the geometry of charge — 1921-1926. A parallel strand emerged from higher-dimensional geometry. Kaluza 1921 and Klein 1926 (Kaluza, 1921, Klein, 1926) showed that an electromagnetic gauge transformation in four dimensions could be realized as a coordinate isometry of an extra dimension, with the electromagnetic potential A_μ identified as a component of the five-dimensional metric. In the constitutional reading of POS-1 GI, Kaluza-Klein is the historical bridge between gauge transformations on the boundary and isometries of the bulk: the five-dimensional Lorentz invariance of the bulk projects to four-dimensional Lorentz invariance plus a $U(1)$ gauge symmetry on the boundary, the prototype of every subsequent bulk-side derivation of boundary gauge structure used by GG-Theory.

5. Dirac monopole and Aharonov-Bohm — 1931 / 1959. Dirac's 1931 paper on magnetic monopoles (Dirac, 1931) demonstrated that consistency of the quantum-mechanical wavefunction in the presence of a monopole forces electric charge to be quantized in integer units of e ($eg = n\hbar c/2$): the first physical example of a continuous parameter being replaced by an integer through a topological consistency requirement. Aharonov and Bohm in 1959 (Aharonov & Bohm, 1959) sharpened the lesson by demonstrating that the holonomy of the gauge connection is physically observable in electron interference even when local field strengths vanish. These two results together established that the gauge connection has *intrinsic* physical content beyond what is locally encoded in $F_{\mu\nu}$ — the foundational empirical motivation for the modern bundle-theoretic reading of gauge fields.

6. Yang-Mills non-Abelian extension — 1954. Yang and Mills (Yang and Mills, 1954) extended the construction to non-Abelian Lie groups, opening the mathematical structure on which the Standard Model (Glashow, 1961, Gross & Wilczek, 1973, Politzer, 1973, Salam, 1968, Weinberg, 1967) would later sit. Yang-Mills theory is, in a precise sense, the non-Abelian completion of Maxwell's gauge freedom: the field strength becomes $F^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + g f^{abc} A^b_\mu A^c_\nu$, the gauge transformation acquires the inhomogeneous term $A_\mu \to U A_\mu U^{-1} + (i/g)\, U\, \partial_\mu U^{-1}$, and the entire structure becomes the fiber bundle of modern geometry. Initially regarded as a curiosity because of the apparent massless-gauge-boson problem, Yang-Mills theory became the spine of all subsequent particle physics once spontaneous symmetry breaking (Higgs) and asymptotic freedom (Gross-Wilczek-Politzer) were discovered.

7. Ward, Takahashi, Slavnov, Taylor — 1950 / 1957 / 1971-1972. The transition to the quantum theory required systematic control of gauge identities at the operator level. John Clive Ward's 1950 paper (Ward, 1950) gave the original Ward identity for QED: the relation $Z_1 = Z_2$ between vertex and electron-wavefunction renormalization constants is forced by gauge invariance, and without it QED would not be renormalizable. Takahashi (Takahashi, 1957) generalized the identity to off-shell external lines, giving what is now called the Ward-Takahashi identity. In the non-Abelian extension, the Slavnov-Taylor identities (Slavnov, 1972, Taylor, 1971) replace simple gauge invariance with the more delicate BRST-cohomology version, and provide the all-orders renormalization control that makes non-Abelian Yang-Mills theory well-defined as a quantum field theory.

8. Faddeev-Popov, BRST, and BV — 1967 / 1976 / 1981. Faddeev and Popov ('t Hooft, 1971, THooft & Veltman, 1972) introduced the path-integral ghost technology needed to compensate the gauge redundancy in the functional measure. Becchi, Rouet, Stora, and Tyutin later recognized that the resulting gauge-fixed action carries a nilpotent fermionic symmetry — BRST symmetry — and that BRST cohomology selects the physical states. Batalin and Vilkovisky (Batalin & Vilkovisky, 1981) generalized the construction to open and reducible gauge algebras via the BV master equation, providing the mathematical apparatus on which the modern field-theoretic quantization of every reducible gauge system rests. In the constitutional reading of POS-1 GI, the BV formalism is what makes the dynamical-gauge-invariance (DGI) layer technically well-defined for the full ladder of gauge structures used by GG-Theory.

9. The geometric formulation — 1950s-1980s. A parallel mathematical synthesis cast gauge theory entirely in the language of fiber bundles. Ehresmann connections, Cartan structure equations, and the principal-bundle picture matured through the 1950s and 1960s. Kobayashi and Nomizu's two-volume *Foundations of Differential Geometry* (Kobayashi & Nomizu, 1963) provided the canonical textbook synthesis; Nakahara's *Geometry, Topology and Physics* (Nakahara, 2003) updated it for the modern generation. The decisive bridge to physics is the Wu-Yang "dictionary" (Wu & Yang, 1975), which translates physicist notation (A_μ, $F_{\mu\nu}$) to mathematician notation (connection one-form, curvature two-form on a principal bundle), and demonstrated that non-trivial bundles (Dirac monopoles, instantons) are mandatory once gauge theory is read geometrically. After Wu-Yang, gauge theory and fiber-bundle geometry are not two languages for the same physics — they *are* the same physics.

10. Wess-Zumino consistency and the cohomological reading — 1971. The recognition that gauge invariance interacts non-trivially with quantization crystallized in the Wess-Zumino consistency conditions (Wess & Zumino, 1971): a gauge anomaly is a cocycle in the gauge-cohomology complex. This is the prefiguration of POS-3 AF: gauge invariance survives quantization only if the anomaly cocycle vanishes (or is canceled by inflow). In the constitutional reading of POS-1 GI, the Wess-Zumino conditions are the algebraic-cohomological statement that local gauge invariance imposes constraints not only on the classical Lagrangian but on the full quantum effective action.

11. ’t Hooft anomaly matching — 1980. ’t Hooft (THooft, 1980) sharpened the discrete content of gauge invariance to an exact non-perturbative constraint: anomaly coefficients are gauge invariants that must match between UV and IR descriptions of any consistent theory. In the constitutional reading of POS-1 GI, anomaly matching is the structural reason discrete gauge data — integer charges, representation indices, generation count — survive RG flow and become *audited* observables. This is the deepest existing technical justification for treating gauge invariance as a primary axiomatic filter rather than a derived feature.

12. Stinespring-Kraus-GKLS and dynamical gauge invariance — 1955 / 1971 / 1976. A separate strand emerged in the open-systems literature. Stinespring’s 1955 dilation theorem (Stinespring, 1955) showed that every completely positive map admits a unitary extension on a larger Hilbert space; Kraus’s operator-sum representation (Kraus, 1971, 1983) provided the working notation; the Gorini-Kossakowski-Sudarshan-Lindblad classification (Gorini et al., 1976, Lindblad, 1976) characterized the most general Markovian quantum dynamics that preserve trace and positivity. When this open-systems language is coupled to the gauge formalism, the requirement of gauge-covariance lifts naturally to generators and channels: an admissible Markov semigroup Φ_t must satisfy $\Phi_t \circ \mathrm{Ad}_{U_g} = \mathrm{Ad}_{U_g} \circ \Phi_t$, extending the closed-system gauge invariance to the open dynamical regime. This is the technical content of the *dynamical-gauge-invariance* (DGI) layer of POS-1 GI.

13. Algebraic and noncommutative-geometry formulations — 1962-1994. A complementary reformulation casts gauge invariance as a statement about the algebra of observables rather than about a specific Lagrangian. Doplicher, Haag, and Roberts (Doplicher, Haag & Roberts, 1971) showed that superselection sectors and statistics can be reconstructed from the algebra of local observables alone; Haag’s monograph (Haag, 1992) provides the canonical synthesis. Connes’ *Noncommutative Geometry* (Connes, 1994) pushes the reformulation further: the Standard Model becomes a spectral-geometric theory in which gauge fields arise as fluctuations of a noncommutative Dirac operator. In the constitutional reading of POS-1 GI, these works show that gauge invariance need not be tied to a specific field-theoretic formulation; it can be stated as a property of the observable algebra, supporting the algebra-first reading used by GG-Theory in its treatment of measurement (AX-3, OGGEP).

14. No-global-symmetry conjecture — 2010-2019. The contemporary philosophical case for the primacy of gauge invariance was crystallized by Banks and Seiberg (Banks & Seiberg, 2011) and sharpened by Harlow and Ooguri (Harlow & Ooguri, 2019): in any consistent theory of quantum gravity, every global symmetry must either be gauged or be broken. Apparent global symmetries are at best approximate; at the deepest level only gauge symmetries are admissible. In the constitutional reading of POS-1 GI, the no-global-symmetry conjecture is the deepest philosophical justification for elevating gauge invariance to the foundational postulate of GG-Theory — whatever the UV completion turns out to be, gauge invariance is the discipline that must be respected.

The axiomatic move of POS-1 GI. POS-1 GI elevates gauge invariance from a structural feature of the standard textbook to an axiomatic precondition for admissibility, layered into three explicit strata: LGI (closed-system local gauge invariance, the Maxwell-Weyl-Yang-Mills tradition), DGI (dynamical gauge invariance for open semigroups, the Stinespring-Kraus-GKLS extension), and GGI (global ledger gauge invariance for the operational dictionary). POS-1 GI first becomes operative at Stratum 1 of Part V, where Maxwell's $U(1)$ gauge action provides the prototype; the layered LGI / DGI / GGI structure is then progressively activated across the higher strata, with Yang-Mills's non-Abelian extension filling out Stratum 2, the dynamical-gauge-invariance layer (open-system equivariance) requiring AX-3 OGGEP and so unlocking at Stratum 3, and the global-gauge-invariance ledger fully structurally locked at Stratum 4. After all, the century-long arc from Faraday's tubes of force through Maxwell's $A_\mu \to A_\mu + \partial_\mu \alpha$, Hilbert-Noether 1915-1918, Weyl's local phase, Kaluza-Klein, Dirac-Aharonov-Bohm, Yang-Mills, Ward-Takahashi-Slavnov-Taylor, Faddeev-Popov-BRST-BV, the fiber-bundle synthesis, Wess-Zumino consistency, 't Hooft matching, Stinespring-DGI, the algebraic-NCG reformulation, and the no-global-symmetry conjecture is a single coherent thread, and POS-1 GI is the axiomatic commitment that any admissible candidate theory must respect every link of it.

26.2 POS-2: Unified Extremal Principle (UEP): PLA $\Longleftrightarrow$ PLT/MEPP/FEP

1. Heron and the ancient extremal tradition — 1st c. The deepest historical anchor for POS-2 UEP is Heron of Alexandria's first-century argument (Heron, c. 1st c.) that light's path of equal angles minimizes the distance — the first recorded extremal principle in physics. Although the proof relied on Euclidean geometry rather than variational calculus, the move is the same one every subsequent physicist has made: identify the dynamics as the stationary point of a scalar.

2. Fermat's principle of least time — 1662. Fermat (Fermat, 1662) derived Snell's law of refraction by demanding that light minimize its travel time in a medium of varying refractive index. Fermat's principle is the historical seed of every variational principle in physics: a single scalar quantity (time, in this instance) whose stationary points pick out the admissible trajectories. In the constitutional reading of POS-2 UEP, Fermat is the deepest historically clean example of the PLT (principle of least time) face of the unified extremal engine.

3. Maupertuis's principle of least action — 1744. Maupertuis (Maupertuis, 1744) extended Fermat's discipline from optics to mechanics: $\delta \int p\, dq = 0$. Maupertuis's principle was initially controversial (he framed it in theological terms, attributing the parsimony to divine economy), but its mathematical content was permanent. Action became, in this single move, the universal currency of dynamics.

4. Euler-Lagrange synthesis — 1744-1788. Euler's 1744 *Methodus inveniendi* (Euler, 1744) established the calculus of variations as a rigorous mathematical discipline; Lagrange's 1788 *Mécanique analytique* (Lagrange, 1788) cast classical mechanics entirely as a variational problem on configuration space. The Euler-Lagrange equations $\partial L/\partial q - (d/dt)\, \partial L/\partial \dot{q} = 0$ became the textbook machinery on which every subsequent variational principle in physics is built.

5. Hamilton's principle — 1834-1835. Hamilton's two essays on general methods in dynamics (Hamilton, 1834, 1835) reformulated mechanics on phase space, introducing what we now call the Hamiltonian and the canonical equations. Hamilton's principle $\delta \int L\,dt = 0$ is the bridge to Hamilton-Jacobi theory and the geometric-optics limit of quantum mechanics (the WKB approximation), supplying the conceptual foundation on which Feynman's path integral would later sit.

6. Onsager's reciprocal relations — 1931. Onsager (Onsager, 1931) extended variational thinking to dissipative systems near equilibrium. The Onsager reciprocal relations $L_{ij} = L_{ji}$ for linear response coefficients are the first systematic statement that the variational structure of physics extends from closed Lagrangian sectors to open thermodynamic ones. Together with the Onsager-Machlup stochastic action (Onsager & Machlup, 1953), this is the boundary-side counterpart of the Lagrangian PLA: the same scalar-functional discipline applied to trajectories with noise.

7. Prigogine's minimum entropy production — 1947. Prigogine (Prigogine, 1947) showed that linear non-equilibrium steady states minimize entropy production. Together with the later generalization by Nicolis-Prigogine (Nicolis & Prigogine, 1977), this established the variational structure of irreversible thermodynamics. In the constitutional reading of POS-2 UEP, Prigogine 1947 is the canonical example of how the variational engine of physics extends from action principles to entropy/free-energy principles — the MEPP face of the unified extremal engine.

8. Jaynes's maximum-entropy principle — 1957. Jaynes (Jaynes, 1957) proposed that the unique unbiased probability distribution consistent with a set of registered constraints is the one that maximizes Shannon entropy. MaxEnt is the information-theoretic dual of action principles: every classical extremal principle has a Bayesian shadow in which the same problem appears as a posterior maximization under a registered prior. In the constitutional reading of POS-2 UEP, Jaynes 1957 is the historical bridge between the dynamical and the inferential faces of the unified extremal engine.

9. Feynman path integral — 1948. Feynman (Feynman, 1948) reformulated quantum mechanics as a sum over histories weighted by $e^{iS[\phi]/\hbar}$. The classical extremal trajectory emerges as the stationary phase of the path integral, and the Schrödinger equation as its high-action limit. This is the cleanest unification of the closed-system PLA with quantum amplitudes; the path integral remains the deepest technical realization of POS-2 UEP in the closed quantum sector.

10. Hamilton-Jacobi and the WKB limit — 1836 / 1926. A separate thread runs from Hamilton-Jacobi theory (1836) to the WKB approximation in quantum mechanics (1926). The Hamilton-Jacobi equation $\partial_t S + H(q, \partial_q S) = 0$ is the geometrical-optics limit of the Schrödinger equation, and the classical extremal trajectory is the stationary phase of the WKB wavefunction. In the constitutional reading of POS-2 UEP, Hamilton-Jacobi/WKB is the technical apparatus that connects the PLA and PLT faces of the unified extremal engine through a single derivation.

11. Stochastic thermodynamics: Jarzynski / Crooks / Seifert — 1997-2012. The modern operational counterpart of variational thermodynamics is the trajectory-level fluctuation-theorem program. Jarzynski (Jarzynski, 1997) derived a non-equilibrium work relation $\langle e^{-\beta W} \rangle = e^{-\beta \Delta F}$; Crooks (Crooks, 1999) sharpened it into a trajectory-level identity; Seifert (Seifert, 2012) surveys the field. These results demonstrate that the variational structure of physics persists at the trajectory level, supplying large-deviation-functional realizations of the unified extremal engine even far from equilibrium.

12. Friston's free-energy principle — 2010. Friston (Friston, 2010) proposed that biological systems minimize a variational free energy that combines information-theoretic surprise with a model-complexity penalty. FEP is the cleanest contemporary demonstration that the same extremal mathematics governs both physics and adaptive biological systems. In the constitutional reading of POS-2 UEP, Friston 2010 supplies the deepest contemporary evidence that the unified extremal engine is not a physics-specific accident but a deep structural property of admissible operational dynamics generally.

13. Modern large-deviation framework — 1998-2009. The contemporary mathematical apparatus that turns variational thermodynamics into a rigorous discipline is large-deviation theory. Freidlin-Wentzell (Freidlin & Wentzell, 1998) for stochastic differential equations and Touchette (Touchette, 2009) for statistical-mechanics applications provide the canonical references. In the constitutional reading of POS-2 UEP, large-deviation theory is the modern probabilistic backbone of every "open-system variational principle" in physics: the path-level quantity $I[y] = \int L(y, \dot{y})\, dt$ that controls rare-event probabilities is the same extremal structure that Onsager-Machlup, Jarzynski, and Friston use in their respective domains.

The axiomatic move of POS-2 UEP. POS-2 UEP does not claim that any single historical extremal principle applies universally as originally stated. It is the constitutional claim that there exists a *single* variational engine, with multiple operational representations (PLA in the bulk, PLT for trajectories, MEPP for currents, FEP for inference) that are duals of each other under the bulk-to-boundary projection of OGGEP. POS-2 UEP is enforced from Stratum 1 onward — Maxwell's variational principle is already a UEP instance — and the open-operational PLT / MEPP / FEP representations unlock at Stratum 3, where AX-3 OGGEP supplies the bulk-to-boundary projection that makes the operational variational forms admissible. After all, the three-and-a-half-century arc from Heron through Fermat, Maupertuis, Euler-Lagrange, Hamilton, Hamilton-Jacobi, Onsager, Prigogine, Jaynes, Feynman, Crooks-Jarzynski-Seifert, Friston, and modern large-deviation theory is a single coherent thread, and POS-2 UEP is the axiomatic commitment that any admissible candidate theory must respect every link of it.

26.3 POS-3: Anomaly freedom and cancellability by inflow (AF)

1. Riemann-Cartan integrability — 1854-1900. The pre-history of anomaly freedom is the integrability tradition of nineteenth-century differential geometry. Riemann's habilitation lecture

(Riemann, 1854) introduced the curvature tensor of a metric manifold and the integrability conditions that any consistent geometry must satisfy. Ricci-Curbastro, Levi-Civita, and the Italian school of absolute differential calculus extended these conditions to arbitrary tensor fields, and Elie Cartan's structure equations (1922-1925) generalized the construction to non-Abelian connections. The Bianchi-type identity $dF + [A, F] = 0$ that every gauge field strength satisfies is, in this tradition, a *geometric* statement about the connection on a principal bundle — it has no quantum content of any kind.

2. Bianchi's identity for Riemann curvature — 1902. Luigi Bianchi's 1902 identity (Bianchi, 1902) extended the integrability tradition to gravity: the Riemann curvature tensor satisfies $\nabla_{[\mu} R_{\nu\rho]\sigma\tau} = 0$, equivalently $dR = 0$ in differential-form language, equivalently $\nabla_\mu G^{\mu\nu} = 0$ for the Einstein tensor. This is the bedrock topological identity from which the entire anomaly story descends. It is what makes the energy-momentum tensor of any matter source automatically conserved when coupled to gravity, and it is the prototype of every subsequent "$dX = 0$" identity in the constitutional reading of POS-3 AF. In Maxwell's electromagnetic theory (Maxwell, 1865) the abelian Bianchi identity $dF = 0$ is the component-form statement of the homogeneous Maxwell equations ($\nabla \cdot \mathbf{B} = 0$, $\nabla \times \mathbf{E} + \partial_t \mathbf{B} = 0$); it holds for any smooth connection on any principal $U(1)$ bundle, regardless of sources, matter content, quantum corrections, or path-integral measure.

3. The Adler-Bell-Jackiw chiral anomaly — 1969. The quantum-field-theoretic side of the anomaly story begins with the 1969 discovery, by Adler (Adler, 1969) and independently by Bell and Jackiw (Bell and Jackiw, 1969), that the axial-vector current of QED is not exactly conserved at the quantum level. The classical chiral symmetry of the massless Dirac action is broken by the triangle diagram, with the divergence picking up a topological-density correction proportional to $F_{\mu\nu}\tilde{F}^{\mu\nu}$. In the constitutional reading of POS-3 AF, the Adler-Bell-Jackiw anomaly is not a pathology of quantum field theory but the AX-3 OGGEP projection shadow of a bulk-side classical-topological identity: the boundary's triangle-diagram measurement of its own inability to register the deeper bulk closure $dX_4 = 0$.

4. Bardeen's non-Abelian extension — 1969. Bardeen (Bardeen, 1969) extended the Adler-Bell-Jackiw calculation to non-Abelian gauge theories, obtaining the closed-form *consistent* anomaly functional $\mathcal{A}^a[A]$ that satisfies the Wess-Zumino consistency conditions. Bardeen's calculation supplies the full local form of the anomaly polynomial on which every subsequent inflow-cancellation construction is built.

5. Wess-Zumino consistency conditions — 1971. Wess and Zumino (Wess & Zumino, 1971) discovered that anomaly candidates must satisfy strong consistency conditions reflecting the group structure of the underlying gauge transformation: the anomaly is a cocycle in the gauge-cohomology complex. This algebraic-topological reading is the seed of the entire modern classification of anomalies as elements of cohomology groups. In the constitutional reading of POS-3 AF, the Wess-Zumino consistency conditions are the algebraic side of the same identity whose differential-geometric side is Bianchi 1902.

6. Atiyah-Singer index theorem — 1963 / 1968. The Atiyah-Singer index theorem (Atiyah & Singer, 1963, 1968) is the mathematical engine behind every subsequent anomaly-cancellation argument: the index of a Dirac operator on a closed manifold equals a topological integral of characteristic classes. In the constitutional reading of POS-3 AF, the Atiyah-Singer theorem is what guarantees that boundary anomalies are locked to bulk topological data; it is the deep mathematical reason why anomaly freedom is, in the end, a question about integers and characteristic classes rather than about renormalization schemes.

7. Fujikawa's path-integral derivation — 1979. Fujikawa (Fujikawa, 1979) showed that the anomaly can be derived non-perturbatively from the non-trivial Jacobian of the fermionic measure under chiral transformations. This identifies the anomaly with a non-trivial determinant of the Dirac operator, recasting it as a global, scheme-independent object. Fujikawa's derivation is the technical foundation of the modern view that anomalies are non-renormalized — they are protected by the index theorem and so cannot be eliminated by any choice of regulator.

8. Chern-Simons forms and characteristic classes — 1974. Chern and Simons (Chern & Simons, 1974) introduced the three-form whose exterior derivative is the second Chern class. Together with the Chern-Weil construction (Chern, 1946, Kobayashi & Nomizu, 1963), this provides the local primitives from which every anomaly polynomial is built. In the constitutional reading of POS-3 AF, Chern-Simons forms are the geometric objects that make inflow cancellation a local, computable identity rather than a formal algebraic rewriting.

9. Stora-Zumino descent equations — 1976 / 1985. Stora (Stora, 1976) and Zumino (Zumino, 1985) cast the full classification of anomalies as a descent chain in BRST cohomology: an anomaly in n dimensions descends from a closed $(n+2)$-form via the Chern-Simons primitive and the BRST differential. This algebraic-topological scaffolding is what turns anomaly classification from a case-by-case calculation into a question about a single chain complex; it is one of the most elegant unifications in twentieth-century mathematical physics.

10. 't Hooft anomaly matching — 1979 / 1980. 't Hooft (THooft, 1980) sharpened the anomaly constraint to an exact non-perturbative consistency condition: anomaly coefficients are RG invariants that must match between the UV and IR descriptions of a theory. In the constitutional reading of POS-3 AF, anomaly matching is the structural reason a discrete anomaly polynomial survives RG flow — the interlock between POS-3 (anomaly cancellation) and POS-5 (RG flow), which is operative across Strata 2 through 4 of Part V.

11. Callan-Harvey anomaly inflow — 1985. Callan and Harvey (Callan & Harvey, 1985) introduced the inflow viewpoint: a chiral anomaly on a boundary or defect is canceled by a bulk topological term that flows charge into the defect, restoring the Bianchi identity at the bulk level. This is the first explicit example in physics of *bulk-cancels-boundary* as a *geometric* identity rather than a quantum miracle. It is the structural template on which BI-6 rests in GG-A3-BI6 (Arisaka, 2026, A3-BI6): the bulk Bianchi $dX_4 = 0$ is a geometric identity, the boundary anomaly is the quantum-level deviation from it, and the four-component bulk inflow $X_4 = dH_3$ closes the loop.

12. Wess-Zumino-Witten topological action — 1983. Witten's 1983 paper (Witten, 1983) on global aspects of current algebra developed the Wess-Zumino term as a topological action in chiral effective field theory and showed that its coefficient is quantized. This is the canonical worked example of how anomaly inflow generates integer-quantized topological couplings on the boundary, providing the cleanest illustration of the POS-3 (anomaly) ↔ POS-6 (OGN) inter-postulate interlock.

13. Green-Schwarz mechanism — 1984. Green and Schwarz (Green and Schwarz, 1984) discovered the ten-dimensional inflow mechanism that saved heterotic string theory from anomalies that would otherwise have killed it: a single counterterm $S_{\mathrm{GS}} = \int B_2 \wedge X_4$ with the modified Bianchi identity $dH_3 = X_4$ cancels the anomaly polynomial of type-I and heterotic strings. This discovery is widely credited as the moment string theory became empirically constrained rather than infinitely flexible. Alvarez-Gaumé and Witten (Alvarez-Gaumé & Witten, 1984) classified gravitational anomalies in arbitrary dimensions in the same year. In the constitutional reading of POS-3 AF, Green-Schwarz is the bulk-side classical absorption of the boundary anomaly — the prototype of the BI-6 identity $dH_3 = X_4$ used by GG-6.

14. Differential cohomology and the modern picture — 2005-2019. *This paragraph is written for readers with a background in algebraic topology. Its content is a pointer to the literature, not a step in the constitutional argument; nothing later in this paper depends on it.*

The contemporary mathematical formulation casts anomalies as *invertible field theories.* Hopkins-Singer (Hopkins & Singer, 2005) differential cohomology turned the anomaly-inflow picture into precise long exact sequences of differential characters; Freed, Hopkins, and Teleman (Freed, Hopkins & Teleman, 2010) provided the categorical scaffolding relating twisted equivariant K-theory of a compact Lie group to its Verlinde algebra; Freed's lecture notes (Freed, 2019) formulated anomalies as partition functions of $(n + 1)$-dimensional invertible TQFTs. In the constitutional reading of POS-3 AF, these works make the geometric-origin-of-anomaly principle mathematically precise: every boundary anomaly is the partition function of a bulk invertible TQFT, so anomaly cancellation is a bulk-side topological identity rather than a quantum cancellation of one-loop pathologies. Bertlmann's monograph (Bertlmann, 1996) surveys the technical apparatus accumulated through the 1990s.

Scope of the constitutional reading. It is worth stating explicitly what POS-3 AF does and does not claim in the constitutional reading. It *does* claim that the boundary 4D "anomaly" of the standard textbook is the AX-3 OGGEP projection shadow of a bulk-side classical-topological identity descended from Bianchi 1902, and that the Green–Schwarz construction is the bulk-side classical absorption of this identity rather than a quantum cancellation of a one-loop pathology. Equivalently, string theory and AdS/CFT — to the extent that they share this bulk-side classical-topological backbone — are structural theorems under AX-2 GGEP (geometrization of gauge fields), *not* under the slogan "quantization of geometry." It *does not* claim to subsume the quantum-dynamical content that string theorists run on top of the classical backbone — graviton vertex operators, α' and $1/N$ corrections, the 2019–2020 islands formula of Almheiri–Engelhardt–Marolf–Maxfield and Penington–Shenker–Stanford–Yang, the Gubser–Klebanov–Polyakov / Witten boundary-operator dictionary, or any of the rich perturbative-string apparatus. The cohort framework occupies the GGEP-closed sector, the classical-topological backbone; the quantum content running on top of that backbone is a separate physical sector that the cohort axioms neither subsume nor contradict. Indeed, we make the qualification explicit so that the seriousness of what POS-3 AF actually claims is not obscured by a misreading as a quantum-gravity displacement claim that the cohort does not make.

The axiomatic move of POS-3 AF. POS-3 AF elevates anomaly freedom from a structural constraint that one verifies case-by-case to an axiomatic precondition for admissibility. Any candidate theory whose anomaly polynomial does not factorize as $X_4 = aR^2 + bF^2_{SU(5)} + cF^2_B + dF^2_{Qi}$ with the trace-ratio lock $|a/c| = |a/d| = 5/2$ fails the POS-3 filter and is rejected. In this reading the four-component identity $(a, b, c, d) = (1, -1, -2/5, -2/5)$ is the axiomatic fingerprint of the entire GG-Theory program, and the geometric Bianchi identity is its parent. POS-3 AF first becomes a non-trivial admissibility filter at Stratum 2 of Part V, where Yang-Mills's non-Abelian curvature and the Green-Schwarz inflow mechanism live; in Stratum 4 the four-component anomaly polynomial locks against the OGN-5 integer ledger. After all, what we name "anomaly freedom" here is the mature, gauge-bundle version of the same conservation-of-current discipline that AX-1 LC imposes on the energy-momentum side — one identity, two faces, both purely geometric.

26.4 POS-4: Closure and positivity (CP)

1. Bernoulli and the law of large numbers — 1713. The mathematical theory of probability begins with Jacob Bernoulli's posthumous *Ars Conjectandi* (Bernoulli, 1713), in which the law of large numbers — the assertion that empirical frequencies converge to underlying probabilities — was first proved. In the constitutional reading of POS-4 CP, Bernoulli is the deepest historical anchor for the discipline that probability, taken operationally as a registered frequency, is a legitimate physical quantity.

2. Bayes and Laplace — 1763 / 1812. Bayes's posthumous essay (Bayes, 1763) introduced inverse probability — the inference of unknown causes from observed effects — in what we now call Bayes' theorem. Laplace's *Théorie analytique des probabilités* (Laplace, 1812) turned the construction into a full analytical apparatus. Together, Bayes and Laplace supplied the inferential machinery that every subsequent quantitative use of probability in physics depends on; in the constitutional reading of POS-4 CP, they are the historical foundation on which Kolmogorov's axiomatization is built.

3. Kolmogorov's axiomatization — 1933. Kolmogorov (Kolmogorov, 1933) supplied the modern axiomatic treatment of probability: probability measures as countably additive non-negative functions on σ-algebras with total mass one. This is the mathematical scaffolding inside which every positivity requirement of POS-4 CP lives. After Kolmogorov, "positive probabilities" became a structural property of the measure space rather than a methodological preference.

4. Born's probability rule — 1926. Born (Born, 1926) fixed the operational meaning of the wavefunction by identifying $|\psi(x)|^2$ with the probability density to register an outcome at x. This is the prototype of every subsequent quantum-probability statement and the historical anchor of the entire operational interpretation of quantum mechanics.

5. Heisenberg-Jordan matrix mechanics — 1925. Heisenberg's 1925 *Umdeutung* paper (Heisenberg, 1925) inaugurated quantum mechanics through the canonical commutation relation $[q, p] = i\hbar$ — the first explicit non-commutative algebra of physical quantities. In the constitutional reading of POS-4 CP, Heisenberg-Jordan is the historical moment at which the algebra of observables became a primary mathematical object, preparing the ground for the algebraic and operational reformulations of the second half of the twentieth century.

6. von Neumann's mathematical foundations — 1932. Von Neumann's *Mathematische Grundlagen der Quantenmechanik* (von Neumann, 1932) formalized the density-matrix description of mixed states, the projection postulate, and the spectral theorem for self-adjoint operators on Hilbert space. This is the textbook foundation of every subsequent operationally rigorous treatment of quantum theory. In the constitutional reading of POS-4 CP, von Neumann 1932 is the canonical statement of closed-system kinematics + unitary closed-system dynamics + projective measurement on which the open-system extensions of POS-4 build.

7. Naimark's dilation theorem — 1940. Naimark (Naimark, 1940) proved that every POVM on a Hilbert space is the compression of a projection-valued measure (PVM) on a larger Hilbert space. This is the structural foundation of operationally-defined measurement: positive operators valued in $[0, 1]$ on $\mathcal{H}$ are always images of orthogonal projections on $\mathcal{H} \oplus \mathcal{H}'$, so the operational generalization loses nothing essential. In the constitutional reading of POS-4 CP, Naimark 1940 is what makes the POVM-based measurement formalism of AX-3 (OGGEP) mathematically well-founded.

8. Stinespring's dilation — 1955. Stinespring (Stinespring, 1955) proved the central structural theorem of open-system dynamics: every completely positive linear map Φ on a C^*-algebra admits a unitary dilation $\Phi(A) = V^\dagger \pi(A) V$ on a larger Hilbert space. Stinespring is the operational definition of complete positivity that has dominated the subsequent literature. Together with Naimark's theorem, it supplies the dilation machinery on which every modern open-system formalism rests.

9. Davies-Lewis instruments — 1970. Davies and Lewis (Davies and Lewis, 1970) introduced the notion of an *instrument* — a CP-map-valued random variable that produces both a post-measurement state and a classical record. Instruments unified "measurement" (one-shot, with readout) and "channel" (no readout) into a single formalism. In the constitutional reading of

POS-4 CP, Davies-Lewis 1970 is the bridge between the ideal projective measurement of von Neumann and the realistic quantum experiment of every twenty-first-century laboratory.

10. Kraus operator-sum representation — 1971. Kraus (Kraus, 1971, 1983) provided the working notation for CP maps: $\Phi(\rho) = \sum_k K_k \rho K_k^\dagger$ with $\sum_k K_k^\dagger K_k \leq \mathbb{1}$. This is the canonical computational form of every modern open-system calculation and the practical embodiment of Stinespring's structural theorem.

11. Choi's matrix and complete positivity — 1975. Choi (Choi, 1975) characterized complete positivity through the Choi-Jamiołkowski isomorphism: a linear map Φ is CP if and only if its Choi matrix $(\mathrm{id} \otimes \Phi)(|\Omega\rangle\langle\Omega|)$ is positive. This is the operational test of physicality on which every contemporary admissibility check rests.

12. Gorini-Kossakowski-Sudarshan-Lindblad master equation — 1976. Gorini, Kossakowski, and Sudarshan (Gorini et al., 1976) and (independently) Lindblad (Lindblad, 1976) classified the most general Markovian generator of a CPTP semigroup: the GKLS form $\dot{\rho} = -i[H, \rho] + \sum_k \gamma_k (L_k \rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\})$ with Kossakowski matrix $(\gamma_k) \succeq 0$. In the constitutional reading of POS-4 CP, the GKLS equation is the technical heart of the dynamical sector: every admissible open-system dynamics in GG-Theory falls in this class. Breuer and Petruccione (Breuer & Petruccione, 2002) and Nielsen-Chuang (Nielsen & Chuang, 2010) codified the construction for the modern generation.

13. Algebraic and constructive QFT — 1956 / 1964 / 1971. A parallel mathematical tradition cast closure and positivity in algebraic language. Wightman's axioms (Streater & Wightman, 1964, Wightman, 1956) require closure of the operator algebra under spacelike commutation; the Haag-Kastler (Haag & Kastler, 1964) formalism extends this to a net of C^*-algebras of local observables indexed by bounded spacetime regions. Doplicher-Haag-Roberts (Doplicher, Haag & Roberts, 1971) demonstrated that the full kinematic structure of a quantum theory — charges, statistics, gauge group — can be reconstructed from the algebra of local observables alone. Haag's *Local Quantum Physics* (Haag, 1992) provides the canonical synthesis. In the constitutional reading of POS-4 CP, this is the algebraic statement of closure plus positivity for a relativistic local quantum theory, completing the bulk side of the postulate.

The axiomatic move of POS-4 CP. POS-4 CP combines algebraic closure (bulk side) with complete positivity (boundary side) into a single admissibility filter. Any candidate theory whose constraints fail to close, or whose boundary semigroup fails to be CPTP, is rejected before its specific content is examined. This rules out a large class of otherwise plausible proposals (post-quantum theories that violate CP, gauge theories with anomalous algebra closure, models that predict negative probabilities at finite times). POS-4 CP first becomes structurally mandatory at Stratum 3 of Part V, where AX-3 OGGEP forces CPTP open dynamics through the Stinespring-Kraus-GKLS chain; classical positivity is already enforced at the lower strata; together with the OGGEP + CP interlock noted in Section 21, this is what makes open-system dynamics axiomatic rather than effective in GG-Theory. After all, the three-and-a-half-century arc from Bernoulli through Bayes-Laplace, Kolmogorov, Born, von Neumann, Naimark, Stinespring, Davies-Lewis, Kraus, Choi, GKLS, and algebraic QFT is a single coherent thread, and POS-4 CP is the axiomatic commitment that any admissible candidate theory must respect every link of it.

26.5 POS-5: RG-compatibility and scale covariance (RG)

1. Buckingham π-theorem and dimensional analysis — 1914. The pre-history of the renormalization group is dimensional analysis. Buckingham's 1914 π-theorem (Buckingham, 1914) stated formally what physicists had always intuited: any physical law expressible in consistent units must be expressible as a relation among dimensionless ratios. Scale invariance is therefore not a special property of a few critical theories — it is the default mathematical structure of every physical law. In the constitutional reading of POS-5 RG, Buckingham is the deepest historical anchor for the discipline that the operational dictionary must commute with rescaling of units.

2. Lamb shift — 1947. The empirical anchor for the modern renormalization program is the Lamb-Retherford measurement of the $2S_{1/2}$–$2P_{1/2}$ splitting in hydrogen (Lamb & Retherford, 1947), demonstrating an unambiguous deviation from the Dirac equation. Bethe's 1947 non-relativistic calculation (Bethe, 1947) explained the splitting by systematically absorbing infinities into a renormalized electron mass — the first demonstration that renormalization is a controlled physical procedure rather than an *ad hoc* subtraction. After Lamb-Bethe, renormalization was no longer optional.

3. Tomonaga-Schwinger-Feynman-Dyson — 1946-1949. The full multi-loop renormalization program is due to Sin-Itiro Tomonaga, Julian Schwinger, and Richard Feynman, with their three approaches unified by Freeman Dyson in 1949. All four shared the 1965 Nobel Prize in Physics for this work. Tomonaga's 1946 paper (Tomonaga, 1946), written at Tokyo Bunrika University during the war years and published in Japanese before becoming widely known in the West, gave the first relativistically invariant treatment of QED in what we now call the interaction picture. Schwinger's 1948 covariant formulation (Schwinger, 1948) carried out the same renormalization program in a manifestly Lorentz-invariant operator language; his calculation of the anomalous magnetic moment of the electron $a_e = \alpha/2\pi$ to one loop was the first quantitative success of renormalized QED. Feynman's 1949 paper (Feynman, 1949) reformulated QED in terms of the diagrammatic calculus that every graduate student now learns; the path-integral construction of 1948 (Feynman, 1948) provided its conceptual underpinning. Dyson's 1949 unification (Dyson, 1949) demonstrated that all three approaches yield identical physical predictions, and introduced the systematic order-by-order expansion in which counterterms are determined by physical renormalization conditions. The Lamb shift, the anomalous magnetic moment, and electron-electron scattering all became finite, calculable predictions in agreement with experiment to many decimal places — the moment quantum field theory stopped being an embarrassment and became a science.

4. Stueckelberg-Petermann — 1953. Stueckelberg and Petermann (Stueckelberg & Petermann, 1953) recognized that the freedom in subtraction schemes generates a *group* action on coupling space: changing the subtraction prescription at scale μ_1 to one at scale μ_2 is a smooth transformation, and the composition law of these transformations is a group. This is the founding observation of the renormalization group proper. In the constitutional reading of POS-5 RG, Stueckelberg-Petermann is the deepest technical justification for treating RG flow as a structural feature of every quantum field theory — not an optional refinement.

5. Gell-Mann-Low — 1954. Gell-Mann and Low (Gell-Mann & Low, 1954) converted the Stueckelberg-Petermann group structure into a concrete renormalization-group equation. The QED running coupling $\alpha(\mu) = \alpha_0/(1 - \alpha_0\beta_0 \log(\mu/\mu_0))$ follows a flow in the energy scale μ, providing the first explicit RGE. Gell-Mann-Low is the textbook moment at which the renormalization group became a calculational tool, not just a structural observation.

6. Kadanoff's block-spin construction — 1966. Kadanoff (Kadanoff, 1966) introduced block-spinning as the physical picture of RG flow in real space: a fine-grained lattice configuration is repeatedly coarsened, and the effective Hamiltonian flows toward a fixed point that characterizes the universality class. This is the iconic concrete realization of RG and the historical bridge between particle-physics renormalization and condensed-matter critical phenomena.

7. Wilson's modern formulation — 1971. Kenneth Wilson's 1971 papers (Wilson, 1971, Wilson & Kogut, 1974) recognized that the renormalization group is not just a technical tool for hiding divergences but a physical statement about how effective theories depend on resolution scale. RG becomes a semigroup on theory space; fixed points classify universality classes; relevant, irrelevant, and marginal operators control the flow in the neighborhood of every fixed point. Wilson's reformulation is widely regarded as one of the deepest conceptual advances in twentieth-century theoretical physics and is the technical heart of POS-5 RG.

8. Callan-Symanzik equations — 1970. Callan (Callan, 1970) and Symanzik (Symanzik, 1970) independently formulated the inhomogeneous RGE $(\mu\partial_\mu + \beta(g)\partial_g - \gamma)\Gamma = 0$ for arbitrary correlation functions Γ, with anomalous dimensions γ supplying the technical apparatus for computing operator scaling. In the constitutional reading of POS-5 RG, Callan-Symanzik is the calculational machinery that lets working physicists turn the abstract commutation $\mathcal{D} \circ \mathrm{RG} = \mathrm{RG} \circ \mathcal{D}$ into concrete quantitative predictions.

9. Polchinski's exact RG — 1984. Polchinski (Polchinski, 1984) derived an exact equation for the Wilsonian effective action: the entire RG can be cast as a continuous functional flow $\partial_t S_{\text{eff}}$ in the action functional. This demonstrated that quantum field theory is, fundamentally, a trajectory in the infinite-dimensional space of admissible Lagrangians. Polchinski's exact RG is the technical foundation on which most modern non-perturbative RG studies rest.

10. Wetterich's effective average action — 1993. Wetterich (Wetterich, 1993) derived a functional RG equation with a sharp infrared cutoff, providing the contemporary computational engine for non-perturbative RG studies. Wetterich's equation is the modern incarnation of Wilson's renormalization group as a functional flow on theory space and supplies the working apparatus by which RG flows are computed in gravity, condensed matter, and effective field theory today.

11. 't Hooft anomaly matching — 1980. 't Hooft (THooft, 1980) sharpened the discrete content of RG flow to an exact non-perturbative consistency condition: anomaly coefficients are RG invariants that must match between the UV and IR descriptions of any theory. This is the first explicit "discrete invariant survives RG" statement and the prototype of the inter-postulate interlock between POS-5 (RG flow) and POS-3 (anomaly cancellation), operative across Strata 2 through 4 of Part V.

12. AdS/CFT and holographic RG — 1997-2001. A separate but converging thread emerged from holography. Maldacena's 1997 AdS/CFT correspondence (Maldacena, 1998), with the bulk-to-boundary dictionary of Witten (Witten, 1998) and Gubser-Klebanov-Polyakov (Gubser, Klebanov, & Polyakov, 1998), identified the radial coordinate of the AdS_5 bulk with the renormalization-group flow direction on the boundary CFT. Scale on the boundary became geometry in the bulk; the renormalization group became a Hamiltonian flow in a higher-dimensional spacetime. De Haro, Skenderis, and Solodukhin (de Haro, Skenderis, & Solodukhin, 2001) formalized holographic renormalization; subsequent work made the radial-evolution picture standard. In the constitutional reading of POS-5 RG, this thread supplies the deepest geometric realization of the RG commutation: the GG-6 radial coordinate r is the RG scale of the boundary, not a free choice.

13. Categorical and TQFT reformulations — 2000s-2020s. The contemporary mathematical formulation casts RG as a *monoidal categorical* coarse-graining and relates the discrete invariants of RG flow (universality classes, anomaly coefficients, central charges) to invertible topological field theories. This unifies the Wilsonian fixed-point classification with the Freed-Hopkins-Teleman categorical view of anomalies (Stratum 3), giving a single mathematical object — the bordism category of admissible TQFTs — that controls every cross-stratum interlock in which RG is involved. In the constitutional reading of POS-5 RG, this is the modern unification that makes the RG-flow content of Strata 2 through 4 indistinguishable from a sub-category of the bulk topological data.

The axiomatic move of POS-5 RG. POS-5 RG elevates scale coherence from a useful empirical regularity to an axiomatic precondition for admissibility: $\mathcal{D} \circ \mathrm{RG} = \mathrm{RG} \circ \mathcal{D}$. Under this discipline the GG-6 radial coordinate r *is* the RG scale, not a free choice; the laboratory does not see the renormalization scheme that the theorist chose, it sees only the scheme-independent physical predictions. POS-5 RG is operative wherever coarse-graining is meaningful: the Wilson RG already enters Stratum 2 of Part V (where Yang-Mills and the renormalization-group flow on theory space first appear), the operational-RG commutation $\mathcal{D} \circ \mathsf{RG} = \mathsf{RG} \circ \mathcal{D}$ requires AX-3 OGGEP and so unlocks at Stratum 3, and the renormalization-group radial RG of the 6D bulk is locked at Stratum 4. After all, the seventy-year arc from Buckingham's π-theorem through the Lamb shift, Tomonaga-Schwinger-Feynman-Dyson, Stueckelberg-Petermann, Gell-Mann-Low, Kadanoff, Wilson, Callan-Symanzik, Polchinski, Wetterich, 't Hooft matching, Maldacena-Witten holography, and the modern categorical synthesis is a single coherent thread, and POS-5 RG is the axiomatic commitment that any admissible candidate theory must respect every link of it.

26.6 POS-6: Occam Gauge Normalization (OGN): rigidity and "no basis drift"

1. William of Occam — early 14th century. The philosophical seed of POS-6 OGN is Occam's celebrated maxim *numquam ponenda est pluralitas sine necessitate* — multiplicity is never to be posited without necessity (Occam, c. 14th c.). In physics the razor takes a stronger and more concrete form than in philosophy: every unexplained continuous parameter is suspicious, and every small dimensionless number that is not protected by a symmetry warrants an explanation.

2. Diophantus of Alexandria — 3rd century. A parallel mathematical tradition gave the same discipline an arithmetic form. Diophantus (Diophantus, c. 3rd c.) posed integer-only problems whose constraints admit only finitely many solutions — the Diophantine equations that bear his name. In the constitutional reading of POS-6 OGN, Diophantus is the deepest historical anchor for the idea that physical predictions can be forced to integer values by simultaneous compatibility constraints rather than fitted from data.

3. Lagrange's four-square theorem — 1770. Lagrange (Lagrange, 1770) proved that every positive integer is the sum of at most four squares. This is the direct arithmetic ancestor of the OGN-5 Diophantine constraint $K = M^2 + N^2 + L^2$ that fixes the lock length of GG-6: a number-theoretic identity from 1770 reappearing in the deepest structural lock of contemporary physics.

4. Hardy-Ramanujan representations — 1918. Hardy and Ramanujan (Hardy & Ramanujan, 1918) developed the circle method for partition counting and the asymptotic theory of integer-representation problems. In the constitutional reading of POS-6 OGN, Hardy-Ramanujan exemplify the modern arithmetic-representation tradition into which the Diophantine $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ ledger naturally fits.

5. Mach's elimination of absolutes — 1893. Mach's *Die Mechanik in ihrer Entwickelung* (Mach, 1893) argued that unexplained continuous absolutes — absolute space, absolute time, absolute mass — should be eliminable from the formulation of physics. Mach's positivist program is the methodological seed of the modern Occam discipline: any continuous quantity that cannot be operationalized should not appear as a fundamental dial.

6. Einstein's complaint — 1933. Einstein (Einstein, 1933) articulated the modern physicist's faith in the parsimony of fundamental laws: "a theorem which at present cannot be based upon anything more than upon a faith in the simplicity, i.e. intelligibility, of nature." In the constitutional reading of POS-6 OGN, Einstein 1933 is the deepest twentieth-century articulation of the principle that POS-6 elevates from preference to axiom.

7. Dirac's monopole and charge quantization — 1931. Dirac's monopole argument (Dirac, 1931) provided the first physical example of a continuous parameter being replaced by an integer through a topological consistency requirement: $eg = n\hbar c/2$. This is the prototype of every subsequent integer-lock in physics, and the historical anchor for the bundle-theoretic strand of POS-6 OGN in which gauge data are forced to take discrete values.

8. Chern-Weil characteristic classes — 1946 / 1974. Chern (Chern, 1946) developed the construction of characteristic classes from the curvature of a connection on a principal bundle, completed by Chern and Simons in 1974 (Chern & Simons, 1974). Chern numbers, Pontryagin numbers, and Stiefel-Whitney classes are integer invariants of the underlying fiber-bundle structure. Once gauge theory is formulated geometrically (Kobayashi & Nomizu, 1963, Nakahara, 2003), these integer invariants are forced. In the constitutional reading of POS-6 OGN, Chern-Weil supplies the modern mathematical justification for the discipline that gauge data must be integers, not fitted constants.

9. Georgi-Glashow grand unification — 1974. The Georgi-Glashow SU(5) model (Georgi and Glashow, 1974) provided the first concrete example of a discrete branching index fixing the abelian normalization of the Standard Model: what looked like three independent continuous couplings became, in the unified description, a single rational ratio set by group embedding. In the constitutional reading of POS-6 OGN, Georgi-Glashow is the canonical example of a continuous parameter being replaced by a rational normalization forced by group theory.

10. Information-theoretic Occam: AIC / MDL / Bayes factor — 1974 / 1978 / 1995. The statistical-inference tradition formalized Occam's razor as a quantitative penalty for unexplained parameters. Akaike (Akaike, 1974) introduced the AIC criterion; Rissanen (Rissanen, 1978) the minimum-description-length principle; Kass and Raftery (Kass & Raftery, 1995) the Bayes-factor framework. These are the modern operational embodiments of the same discipline that POS-6 OGN elevates to axiomatic status: every additional continuous parameter pays a quantitative penalty.

11. String landscape and swampland — 2003-2005. String compactifications produced an estimated 10^{500} inequivalent four-dimensional theories, each with its own continuous moduli, none picked out by an identifiable principle (Douglas, 2003, Polchinski, 2004, Susskind, 2003). Vafa's swampland conjectures (Vafa, 2005) responded by attempting to identify selection rules; weak-gravity, distance, and de-Sitter conjectures supply candidate constraints. In the constitutional reading of POS-6 OGN, the minimum-rationality discipline of OGN is the natural endpoint of this long search: where the landscape exhausted continuous freedom and the swampland conjectures sought to restrict it, OGN insists that the surviving freedom must be *integer*.

12. Modern philosophy of parsimony — 2015. Sober's *Ockham's Razors* (Sober, 2015) provides the contemporary philosophical defense of minimum-parameter model selection. Sober demonstrates that the discipline of parsimony, properly formalized, is rationally justifiable and not merely an aesthetic preference. In the constitutional reading of POS-6 OGN, Sober is the modern philosophical justification for elevating Occam's razor from a heuristic to a constitutional axiom.

The axiomatic move of POS-6 OGN. POS-6 OGN elevates "no free dials in conventions, every continuous freedom either forced or absent" from a methodological preference to an axiomatic filter. The OGN-5 ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ is the unique integer solution that satisfies the simultaneous Diophantine constraints $K = LJ = M^2 + N^2 + L^2$, $J = 2N + 1$ together with the four-component anomaly polynomial T5. POS-6 OGN is enforced at Stratum 4 of Part V, where AX-4 MSMF locks the bulk to a unique integer ledger and shuts the door on every continuous freedom not forced by symmetry, consistency, or operational meaning. This is the first time a physical theory has produced its fundamental constants as the output of a Diophantine system rather than as continuous fitted parameters — a development that places GG-Theory in the long tradition of attempts to realize Occam's razor as exact arithmetic constraint, but with a concrete result rather than a methodological promise. After all, the seven-century arc from William of Occam through Diophantus (re-read), Lagrange's four-square theorem, Hardy-Ramanujan, Mach, Einstein, Dirac, Chern-Weil, Georgi-Glashow, AIC/MDL, the string landscape, and modern Sober is a single coherent thread, and POS-6 OGN is the axiomatic commitment that any admissible candidate theory must respect every link of it.

26.7 POS-7: Measurement and falsifiability (MF): compile-to-observable

1. Aristotle and the empirical tradition — 4th century BCE. Aristotle (Aristotle, c. 350 BCE) grounded natural philosophy in observation of phenomena: every claim about the natural world must, in his formulation, be answerable to what can be seen and measured. In the constitutional reading of POS-7 MF, Aristotle is the deepest historical anchor for empiricism — the discipline that whatever a theory claims must ultimately compile to a registered observation.

2. Galileo and the operational turn — 1610-1638. Galileo (Galilei, 1632) made physics an operational discipline. His instruments (telescope, inclined plane, pendulum, hydrostatic balance) turned natural philosophy from a contemplative activity into a measurement program: a quantity that no instrument procedure can pin down is not a quantity that physics can use. This is the empirical seed of every subsequent operational interpretation of physical concepts.

3. Bridgman's operationalism — 1927. Bridgman (Bridgman, 1927) sharpened the Galilean discipline into an explicit principle: the meaning of a physical concept is the set of operations by which it is measured. Bridgman's operationalism, often criticized as too narrow when read literally, captures the necessary discipline that every POS-7 MF measurement contract inherits: a quantity that no instrument procedure can pin down is not a quantity that the constitution admits.

4. Heisenberg uncertainty — 1927. Heisenberg (Heisenberg, 1927) formalized the trade-off between conjugate observables: $\Delta q \cdot \Delta p \geq \hbar/2$. This was the first explicit demonstration that *what is measurable* is constrained by the algebra of observables itself, not merely by instrumental limitations. In the constitutional reading of POS-7 MF, Heisenberg 1927 is the canonical reminder that the audit-contract requirement of POS-7 cannot be a naive prescription; it must take seriously the algebraic structure of what a quantum system permits one to ask.

5. von Neumann's projection postulate — 1932. Von Neumann (von Neumann, 1932) provided the first textbook treatment of the measurement process: a measurement of an observable A projects the state onto an eigenspace of A with Born probabilities. This is the canonical statement of the measurement problem in classical quantum theory — the problem that POS-7 dissolves by re-reading measurement through the OGGEP operational dictionary and the modern instrument formalism.

6. Neyman-Pearson hypothesis testing — 1933. Neyman and Pearson (Neyman & Pearson, 1933) formulated the likelihood-ratio test, type-I and type-II errors, and pre-declared rejection regions. This supplies the quantitative apparatus that makes "kill criterion" a precise statistical-decision notion: a falsifier is a pre-declared rejection region R_α at significance level α. In the constitutional reading of POS-7 MF, Neyman-Pearson is the technical core of the $(\mathcal{I}, \mathcal{S}_{\text{valid}}, \mathcal{T}, K)$ tuple's final entry.

7. Popper's falsifiability — 1934 / 1959. Popper's *Logik der Forschung* (1934, English translation 1959) (Popper, 1959) gave the canonical modern formulation: a scientific theory is one that makes *falsifiable* predictions, i.e. predictions that some conceivable observation could refute. Popper's demarcation criterion is the philosophical core of POS-7 MF: every claim must specify, in advance, what observation would falsify it.

8. Shannon's information theory — 1948. Shannon (Shannon, 1948) introduced the quantitative theory of information — bits, entropy, channel capacity, mutual information. This supplies the natural language for "registered observable" and "informativeness of a measurement contract": a contract that returns one bit of information is operationally worth less than one that returns many bits, and Shannon's framework makes the comparison precise.

9. Kullback-Leibler relative entropy — 1951. Kullback and Leibler (Kullback & Leibler, 1951) introduced the relative-entropy or KL-divergence pre-metric between predicted and observed distributions. In the constitutional reading of POS-7 MF, KL-divergence is the canonical information-theoretic distance between the predicted and observed distributions of a registered estimator, and the foundation of likelihood-ratio decisions in modern statistical practice.

10. Kuhn, Lakatos, Feyerabend — 1962-1975. Kuhn's *Structure of Scientific Revolutions* (Kuhn, 1962) challenged the simple-falsifiability picture by emphasizing paradigm shifts; Lakatos (Lakatos, 1970) refined Popper to research programs with a hard core and protective auxiliary hypotheses; Feyerabend (Feyerabend, 1975) rejected demarcation altogether in *Against Method*. Modern philosophy of science recognizes that Popper's criterion is necessary but not sufficient: a falsifier must be specific, pre-declared, and operationally checkable rather than post-hoc. In the constitutional reading of POS-7 MF, this trio is the philosophical context against which the modern pre-registration discipline is the working-physics response.

11. Davies-Lewis-Kraus-Ozawa-Busch-Nielsen-Chuang: the operational QM tradition — 1970-2010. The modern operational formalism for quantum measurement matured through the second half of the twentieth century. Davies and Lewis (Davies and Lewis, 1970) introduced instruments; Kraus (Kraus, 1971, 1983) the operator-sum representation; Ozawa (Ozawa, 1984) the formalism for sequential measurement; Busch, Lahti, and Mittelstaedt (Busch, Lahti, & Mittelstaedt, 1996) the unified operational + philosophical treatment; Nielsen and Chuang (Nielsen & Chuang, 2010) provided the modern textbook synthesis. In the constitutional reading of POS-7 MF, this is the technical content imported wholesale by the postulate — the apparatus on which every measurement contract relies.

12. Bell's theorem and experimental violation — 1964 / 1972-2015. Bell (Bell, 1964) derived inequalities that any local-hidden-variable theory must satisfy. Freedman and Clauser (Freedman & Clauser, 1972) performed the first experimental test; Aspect (Aspect, Dalibard, & Roger, 1982) sharpened it with time-varying analyzers; Hensen et al. (Hensen et al., 2015) and Giustina et al. (Giustina et al., 2015) performed the first loophole-free violations. In the constitutional reading of POS-7 MF, Bell + Aspect + the loophole-free experiments are the most consequential modern falsifiability contract in the foundations of physics: a pre-declared inequality was tested, the test was passed, and quantum mechanics survived where any local hidden-variable theory could not.

13. Pre-registration and registered reports — 2010-2020s. The contemporary empirical-science culture of pre-declared protocols, pre-registered analyses, and registered replications is the working-physics response to the philosophical refinements of Kuhn, Lakatos, and Feyerabend. Registered reports, pre-analysis plans, and replication studies have become standard in particle physics, cosmology, condensed-matter, and (increasingly) the biological and social sciences. In the constitutional reading of POS-7 MF, the pre-registration culture is the contemporary operational embodiment of the discipline that the postulate elevates from empirical practice to axiomatic requirement.

The axiomatic move of POS-7 MF. POS-7 MF combines all of these strands into a single audit requirement. Every theoretical claim in GG-Theory must compile, via the operational dictionary OGGEP, to a registered observable, an instrument protocol, and a pre-declared falsification (kill) criterion. Claims that cannot be compiled into such a measurement contract are not admissible as scientific statements within GG-Theory. This is operationalism plus Popperian falsifiability plus Neyman-Pearson hypothesis testing plus Shannon-Kullback information theory plus the modern instrument formalism, all elevated from a methodological add-on to an axiomatic precondition. POS-7 MF first becomes a non-trivial admissibility contract at Stratum 3 of Part V, where AX-3 OGGEP defines what measurement means in operational terms; the pre-registered kill-criterion contract is fully locked at Stratum 4, where the OGN-5 integer ledger supplies the sharp numerical predictions that the measurement contract is then required to register. After all, the two-and-a-half-millennium arc from Aristotle through Galileo, Bridgman, Heisenberg, von Neumann, Neyman-Pearson, Popper, Shannon, Kullback-Leibler, Kuhn-Lakatos- Feyerabend, Davies-Lewis-Kraus-Ozawa-Busch-Nielsen-Chuang, Bell-Aspect-Hensen-Giustina, and modern pre-registration is a single coherent thread — and POS-7 MF is the axiomatic commitment that any admissible candidate theory must respect every link of it. This is the most important thing the constitution can do for the working scientist: it converts the loose phrase "my theory makes predictions" into a checkable contract.

Closing remarks on Part III

The eleven clauses are now complete. Four axioms said what kind of object a theory is; seven postulates said which such objects survive. That is the whole constitution, and it is short enough to read again before dinner.

Of the seven filters, six are recognizable as good practice made explicit. Working physicists already insist on gauge invariance, already derive from variational principles, already cancel anomalies, already keep probabilities positive, already check that answers do not depend on the cutoff. Writing these down changes little in daily practice and much in accountability: a stated rule can be checked against, and a habit cannot.

The seventh is different, and we want to end this Part on it. POS-7 MF requires that a claim name, in advance, the measurement that would kill it. Not a measurement that would support it — support is cheap, and a sufficiently flexible framework can be supported by anything. The requirement is that the theory say, before the data arrive, what result it could not survive.

This is harder than it sounds, and the difficulty is worth feeling. Consider a prediction like "the matter fraction of the universe is $1/\pi$". Stated loosely, it is nearly unfalsifiable: measurements carry error bars, $1/\pi \approx 0.3183$ sits close to the observed value, and a determined defender can always plead that the next dataset will settle it. Stated as a contract — a named observable, a resolution threshold, a numerical deviation, a significance level, all fixed in advance — it becomes a claim that can die on a specific Tuesday. The consolidated table in the next Part does exactly this for ten predictions.

We think the honesty here is technical rather than moral. A theory that cannot lose is not being generous; it is failing to carry information. Information, in the precise sense, is what is left after possibilities have been excluded, and a claim that excludes nothing tells you nothing. The demand that physics name its own kill criteria is not a demand for humility. It is a demand that the claims mean something.

The constitution is now stated in full. What it does not contain is the proof that these eleven clauses force anything at all — that work is long, and it lives elsewhere. Part IV is the map to where.

Part IV
Forward Map and Bridges to the Companion Papers

Where Each Theorem Lives in the GG6, GDOS, 4D-Physics, Capstone, Foundations, Predictions, Cosmology and White-Paper Cohort

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This Part proves nothing. It is the index.

By this point the constitution is complete: four axioms and seven postulates, eleven clauses, stated in full. What the constitution does *not* contain is the hard technical work of showing that those eleven clauses actually force a six-dimensional geometry, an exact anomaly identity, a boundary law for open systems, and a specific list of numbers. That work exists, but it is long — long enough that carrying it here would make this document unusable as a rule-set. So it lives in twenty-one companion papers, and this Part is the map to them.

The arrangement deserves a defense rather than an apology. A legal constitution is short on purpose. A document long enough to contain its own case law is too long to audit *as* a constitution, and a rule-set nobody can hold in mind stops working as a rule-set. The price of keeping this one short is that the reader must sometimes follow a pointer, and we have tried to make every pointer exact.

You will find here: a full inventory of the twenty-two papers and what each carries; a short bridge to each branch of the program, saying what that branch is for; a coherence map tying each of the eleven Principal Theorems to the specific numbered theorem in the specific companion paper where it is proved; the five universal constants the program claims to reconstruct; a minimum reading path for someone who wants to evaluate the central claims without reading all twenty-two documents; and a consolidated table of every sharp numerical prediction together with the measurement that would falsify it.

If you read one thing in this Part, read that last table. It is the shortest honest summary of what this program is betting.

27 The axiomatic handoff

GG-Theory is a coordinated program of foundational papers, of which the present paper is the first. Section 27.1 records the comprehensive inventory of those papers; the figure in Section 27.2 shows their relations as a single flowchart; Sections 27.3 through 27.9 bridge to each companion paper in turn, naming what it carries; and Section 27.10 pins each Principal Theorem Tk to the canonical theorem location in the companion paper where its proof actually lives. This Part is the navigator the reader uses to find the rest of the program.

27.1 Comprehensive paper inventory

The GG-Theory program organizes into an axiomatic root (this paper, Arisaka-GG-A1-Constitution), a **GG6 Trio** of bulk-side foundational papers (A2–A4), a **GDOS Trio** of boundary-side foundational papers (A5–A7), a **4D-Physics Trio** of operational and numerical-derivation papers (A8–A10), a closing capstone (A11), a **Foundations Branch** of two further foundational member papers (P4–P5), two extensible phenomenology branches — a **Predictions Branch** of particle-physics papers (P1–P3, P6) and a **Cosmology & Astrophysics Branch** (C1–C3) — and a **White-Paper Branch** (W1–W2) of two synthesis papers that read the cohort rather than extend it. Twenty-two papers in all. A compilation Foundation Book and a popular exposition round out the series for broader audiences. Table 5 records the master inventory. One reading aid for the GDOS Trio: its three members are the three tenses of AX-3 — the *law* (GG-A5-GDOS), the *runtime* (GG-A6-GRIP), and the *selector* (GG-A7-Qi4) — strung together by the boundary descent chain of Derivation 4 (Eq. 41).

Table 5: Comprehensive inventory of the GG-Theory papers. The axiomatic root, three trios, the closing capstone, the two-paper Foundations Branch, two extensible phenomenology branches, and the two-paper White-Paper Branch compose the twenty-two-paper GG-Theory program. Each row records the paper's name, which links to its entry in the bibliography, a short description of the paper's role, the constitutional source (which AX or POS forces it), the Principal Theorem(s) it carries, and the trio grouping where applicable. All foundational papers exist as released preprints in the versions named.

Name	Short title	Role	Carries	Group
Arisaka-GG-A1-Constitution	The GG-Constitution	*This paper.* Four axioms, seven postulates, definitions, historical motivation, forward map.	None — names T1–T11, proves none.	Root
Arisaka-GG-A2-GG6	GG-6 Foundation	Establishes the 6D bulk; the four-factor composite gauge group $\mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$; the OGN-5 integer ledger $(1, 3, 5; 7, 35)$.	T1 Locked Equivalence; T3 Anti-Landscape; T4 6D bulk; T6 OGN-5 as bulk output.	GG6 Trio
Arisaka-GG-A3-BI6	BI-6 Anomaly Proof	Hopkins-Singer differential-cohomology proof of the Green-Schwarz exact descent. The trace-ratio lock $\lvert a/c\rvert = \lvert a/d\rvert = 5/2$ is the axiomatic fingerprint of the program.	T5 BI-6 four-component anomaly identity.	GG6 Trio
Arisaka-GG-A4-Euclid	From Euclid to GG-6	Historical-view companion: the 2300-year chain from Euclid to the GG-6 stage, plus the parameter audit and master derivation table that synthesize the Ultra Seven into one zero-free-parameter ledger. Pedagogical and synoptic; theorem-bearing content is delegated to the source papers.	None (commentary on T4–T6; synoptic on T1–T11).	GG6 Trio
Arisaka-GG-A5-GDOS	GDOS Foundation	Establishes the boundary law $\mathcal{L}_{\mathsf{GDOS}}$; recovers QM, GR, QFT as 4D boundary projections of the 6D bulk under OGGEP.	T2 Operational Closure; T7 4D QM; T8 4D GR; T9 4D QFT.	GDOS Trio

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Name	Short title	Role	Carries	Group
Arisaka-GG-A6-GRIP	Gi-4 Pillars	Four pillars on the geometric flank of the boundary law: TGG, CCI, GFF, GRIP (the cascade DGI → GSSB → GA/GGA, two regimes GRIP-In/GRIP-Out).	T10 Gi-4 pillars.	GDOS Trio
Arisaka-GG-A7-Qi4	Qi-4 Pillars	Four pillars on the quantum-information flank: Qi-QUA, Qi-EP, Qi-CON, Qi-HAL.	T11 Qi-4 pillars.	GDOS Trio
Arisaka-GG-A8-QM	4D Quantum Mechanics	Operationalizes T2 and T7 from A5 into a concept-by-concept reformulation of textbook QM — Born rule, EPR, Bell–CHSH, Schrödinger's cat, decoherence. Closes with the *Einstein-in-6D, Bohr-in-4D* thesis.	None new — operational reformulation.	4D-Physics Trio
Arisaka-GG-A9-SM	Standard Model derivation	Numerical descent: derives the 28 continuous parameters of the Standard Model from $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ and the 6D bulk.	None new — numerical descent.	4D-Physics Trio
Arisaka-GG-A10-Cosmos	Cosmology derivation	Numerical descent: derives $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$, $\Omega_b = 1/(2\pi^2)$, $\Omega_{\mathrm{DM}} = 1/\pi - 1/(2\pi^2)$, $m_\Lambda \approx 6$ meV.	None new — numerical descent.	4D-Physics Trio
Arisaka-GG-A11-Origin†	Closing Capstone	Closes the A-series: the Ground Geometric Attractor (GGA) and the identity cascade that runs from the gauge symmetry breaking through atomic ground states to life and mind, read as one sequence of forced identities rather than as an analogy.	None new — the closing identity cascade.	Capstone
Arisaka-GG-P1-KK	KK Lock Cluster	Phenomenology: non-spatial Kaluza-Klein cluster (RG-scale) at $M_{\mathrm{lock}} \approx 3.85$ TeV with specific LHC and future-collider falsifiers.	None new — phenomenology.	Predictions
Arisaka-GG-P2-N3	Three Generations	Phenomenology: three-leg derivation of the family number $N = 3$ from BI-6, MSMF, and GDOS Morse stability, with its conditioning declared.	None new — phenomenology.	Predictions
Arisaka-GG-P3-Electron	Electron as Ground State	Phenomenology/review: the six oldest electron questions — identity, stability, copies, the positron, pointlikeness, sensing — closed as one ground-state theorem-complex, every fence declared.	None new — phenomenology.	Predictions
Arisaka-GG-P4-Real	The Origin of i	Foundations: both complex structures of physics derived from two real bulk sources — the compact phase circle (the gauge i) and the causal clock (the state-space i) — with the antiparticle handshake as their forced agreement.	None new — foundations development (theorem keys T-P4-N).	Foundations

continued on next page

Name	Short title	Role	Carries	Group
Arisaka-GG-P5-CPT	The Mirrors of Matter	Foundations: C, P, and T derived as orientation reversals of the three real bulk factors; CPT as the undetectable total reversal; the cosmic matter excess routed through the flavored chain, its sign carried by the Majorana parity (derived-conditional).	None new — foundations development (theorem keys T-P5-N).	Foundations
Arisaka-GG-P6-Proton	The Guarded Proton	Phenomenology: the proton as the GGA of the baryonic stratum, with baryon number carried as a winding of the compact geometry, so that its stability is a theorem rather than an accident. Eleven questions closed as faces of one fact.	None new — phenomenology.	Predictions
Arisaka-GG-C1-Kaxion	Kaxion Dark Matter	Phenomenology: kaxion oscillation $\Delta\nu/\nu = 1/35$ with specific haloscope/cavity falsifiers.	None new — phenomenology.	Cosmology
Arisaka-GG-C2-Hubble	Hubble Tension	Phenomenology: the two measured Hubble constants as the two ends of one six-dimensional geometric corridor.	None new — phenomenology.	Cosmology
Arisaka-GG-C3-BH	Black-Hole Entropy	Phenomenology: the horizon as an OGGEP port; exact Bekenstein–Hawking $A/4$ from induced gravity.	None new — phenomenology.	Cosmology
Arisaka-GG-W1-Symmetry	Conservation without Symmetry	Synthesis, *diachronic*: the century from Noether to Hopkins–Singer quantization, showing the conviction "symmetry causes conservation" loosening at seven historical steps, with the program placed at the arc's end at declared grades.	None — carries every result at its parent's declared grade.	White Paper
Arisaka-GG-W2-Holonomy	Sixteen Open Problems	Synthesis, *synchronic*: one exact statement — the circle remembers and the interval forgets — followed to sixteen of the questions physics has not closed, with the named measurements on which six of the treatments die.	None — carries every result at its parent's declared grade.	White Paper

† GG-A11-Origin is in preparation and is not among the posted papers; it is listed here because it is part of the program's architecture, and no result of the present paper depends on it.

27.2 Relations among the GG-Theory papers

The relations among the papers are the descent flowchart of Figure 3, printed in Part I where a first-time reader meets the cohort; each downward step there is labeled by the AX or POS that drives it. Read against Table 5 above, the plate says which paper inherits from which, and the table says what each one carries.

27.3 Bridge to the GG6 Trio (A2, A3, A4)

Indeed, AX-2 GGEP together with POS-3 AF, POS-5 RG, and POS-6 OGN forces the existence of a specific six-dimensional bulk realization of the composite geometric-gauge connection. The GG6 Trio supplies this bulk realization in three complementary forms: GG-A2-GG6 establishes the 6D bulk and the four-factor composite gauge group; GG-A3-BI6 supplies the differential-cohomology proof of the four-component anomaly identity; and GG-A4-Euclid records the historical lineage that leads to the GG-6 stage.

What GG-A2-GG6 (Arisaka, 2026, A2-GG6) carries. The canonical 6D bulk metric $ds_6^2 = \mathrm{e}^{-2r}\,\eta_{\mu\nu}\,dx^\mu dx^\nu + dr^2 + d\theta^2$ with $r \in [0, K = 35]$ and $\theta \in [0, 2\pi)$; the four-factor composite gauge group $G_{\mathrm{tot}} = \mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$; the OGN-5 integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ satisfying the Diophantine consistency $K = LJ = M^2 + N^2 + L^2$; the boundary at $r = 0$ supplying the unification scale $E_{\mathrm{GUT}} \approx 2.28 \times 10^{16}$ GeV; the lock cluster at $r = K$ supplying $M_{\mathrm{lock}} \approx 3.85$ TeV. Carries Principal Theorems T1 Locked Equivalence, T3 Anti-Landscape Selection, T4 6D bulk Existence, and T6 OGN-5 as Bulk Output.

What GG-A3-BI6 (Arisaka, 2026, A3-BI6) carries. The Hopkins-Singer differential-cohomology proof that the four-component anomaly polynomial $X_4 = a\ \mathrm{tr}(R \wedge R) + b\ \mathrm{tr}(F_{\mathrm{SU}(5)} \wedge F_{\mathrm{SU}(5)}) + c\,F_B \wedge F_B + d\,F_{Qi} \wedge F_{Qi}$ admits exact Green-Schwarz descent if and only if $(a, b, c, d) = (1, -1, -2/5, -2/5)$, with the geometry-gauge trace-ratio lock $|a/c| = |a/d| = 5/2$ as the axiomatic fingerprint of the program. Carries Principal Theorem T5.

What GG-A4-Euclid (Arisaka, 2026, A4-Euclid) carries. The historical-view companion: the long chain from Euclid through Newton, Riemann, Maxwell, Einstein to the GG-6 stage. This is not a theorem-bearing paper but a pedagogical commentary that locates the bulk-side foundational moves in the long chain of geometric-foundational thought.

27.4 Bridge to the GDOS Trio (A5, A6, A7)

AX-3 OGGEP acting on the 6D bulk of A2 forces the boundary law $\mathcal{L}_{\mathsf{GDOS}}$ on the 4D slice $M_4 = \partial\mathcal{M}_6$. The GDOS Trio supplies this boundary side: GG-A5-GDOS establishes the boundary law itself; GG-A6-GRIP and GG-A7-Qi4 decompose the boundary law into four geometric-invariance pillars and four quantum-information pillars respectively.

What GG-A5-GDOS (Arisaka, 2026, A5-GDOS) carries. The boundary CPTP channel $\Phi_{t,s} : \rho_{\mathrm{Bdy}}(s) \mapsto \rho_{\mathrm{Bdy}}(t)$ via Stinespring dilation; the GKLS form of the generator $\mathcal{L}_{\mathsf{GDOS}}$; the recovery of textbook quantum mechanics, general relativity, and quantum field theory as boundary-projection theorems on the 4D slice; the Born rule and the projection postulate as theorems rather than as separate axioms; the modified Tolman-Oppenheimer-Volkoff equation; the BRST cohomology and the Slavnov-Taylor identities. Carries Principal Theorems T2 Operational Closure, T7 4D QM, T8 4D GR, and T9 4D QFT.

What GG-A6-GRIP (Arisaka, 2026, A6-GRIP) carries. The four geometric-invariance pillars descending from AX-3 OGGEP on the geometric flank: TGG (Total Geometric-Gauge object), CCI (Covariant Conservation Identity), GFF (Geometric Free-Energy Functional), GRIP (Gauge-Runtime Invariance Pipeline, the cascade DGI → GSSB → GA/GGA with finite-budget closure, run in the two regimes GRIP-In/GRIP-Out). Carries Principal Theorem T10.

What GG-A7-Qi4 (Arisaka, 2026, A7-Qi4) carries. The four quantum-information pillars descending from AX-3 OGGEP on the operational flank: Qi-QUA (qua-state preparation), Qi-EP (quantum equivalence principle), Qi-CON (decoherence and contraction, recovering einselection), Qi-HAL (holographic alphabet bound on boundary information density). Carries Principal Theorem T11.

27.5 Bridge to the 4D-Physics Trio (A8, A9, A10)

Indeed, the GDOS Trio supplies the abstract boundary law; the 4D-Physics Trio operationalizes that law into the concrete physics any laboratory or telescope can register. GG-A8-QM reformulates textbook quantum mechanics in GDOS language; GG-A9-SM derives the 28 continuous parameters of the Standard Model from the OGN-5 ledger; GG-A10-Cosmos derives the cosmological partitions of ΛCDM.

What GG-A8-QM (Arisaka, 2026, A8-QM) carries (preprint pending — two parallel manuscripts being merged). The concept-by-concept reformulation of textbook quantum mechanics in the language of GDOS and OGGEP: the Born rule as a theorem of the Stinespring dilation rather than as an axiom; the EPR paradox, the Bell inequality, the CHSH inequality, the Aspect (1982) experiment, and the loophole-free experiments (Giustina et al., 2015, Hensen et al., 2015) reframed as evidence that the 6D-to-4D projection is not invertible; Schrödinger's cat ("dead-and-alive in 6D, decohered in 4D"); the double-slit; quantum decoherence and einselection. The paper closes with the central GG-Theory thesis: *Einstein was right in 6D — Nature does not play dice; Bohr was right in 4D — the 4D observer cannot avoid the dice; both positions are correct within their respective domains.* Operationalizes T2 and T7 from A5; carries no new Principal Theorem of its own.

What GG-A9-SM (Arisaka, 2026, A9-SM) carries. The numerical descent that produces the 28 continuous parameters of the Standard Model from $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ via the 6D bulk: the three gauge couplings g_1, g_2, g_3; the nine charged-fermion masses; the four CKM parameters; the three neutrino masses and the four PMNS parameters; the QCD theta angle $\bar{\theta}$; the cosmological constant Λ; the Newton constant G_N. Each parameter pinned by a closed-form expression in the OGN-5 integers.

What GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) carries. The numerical descent that produces ΛCDM as boundary cosmology of the 6D bulk: $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$, $\Omega_b = 1/(2\pi^2)$, $\Omega_{\rm DM} = 1/\pi - 1/(2\pi^2)$; $m_\Lambda = M_{\rm lock}^2/M_{\rm Pl} \approx 6\,\text{meV}$; the electroweak scale $v = M_{\rm lock}\,(2/5)^3 \approx 246\,\text{GeV}$.

27.6 Bridge to the closing capstone (A11)

GG-A11-Origin closes the A-series. Where GG-A8-QM, GG-A9-SM and GG-A10-Cosmos read the boundary law out into quantum mechanics, the Standard Model and ΛCDM, the capstone asks what the same machinery says once it is allowed to run all the way up.

What GG-A11-Origin (Arisaka, 2026, A11-Origin) carries. The Ground Geometric Attractor (GGA) and its ground-state refinement, together with the GRIP-In/GRIP-Out regime theorems and the identity cascade that runs from gauge symmetry breaking through atomic ground states to life and mind — presented as a sequence of forced identities at declared grades, with the structural claim that the sequence is one mechanism rather than an analogy flagged, in the paper's own words, as the most contestable claim of the program. Carries no Principal Theorem of the present paper.

27.7 Bridge to the Foundations Branch (P4, P5)

On the map's left flank, the Foundations Branch carries the origin of the boundary's complex structure and the discrete-symmetry / matter interface — the two member papers that answer, from the real oriented bulk, the questions every consumer of the quantum formalism otherwise inherits silently: where the i comes from, and why the mirrors break.

What GG-P4-Real (Arisaka, 2026, P4-Real) carries. The derivation of the complex numbers of physics from two real structures of the 6D bulk: the charge circle's quarter-turn as the unique circle-compatible complex structure on every charged sector (T-P4-1, the gauge i); the causal clock's polar phase as the unique positive-energy, dynamics-commuting complex structure (T-P4-2, the state-space i); their forced on-shell agreement under the Feynman–Stückelberg pairing — antiparticles as a consistency condition rather than a postulate (T-P4-3); the shared complex structure on composites (T-P4-4); and the bridge that positive frequency *is* holomorphy at the Hardy, forward-tube, and twistor levels (T-P4-6/7). Grade, stated honestly: derived at the quasi-free grade; the interacting extension is conditional on the named hypotheses (H1)–(H3) of T-P4-8. Feeds GG-A8-QM's real-bulk series and the primitive-category pricing of L-Constitution-1 (§8.5, candidate grade). Carries no Principal Theorem of the present paper.

What GG-P5-CPT (Arisaka, 2026, P5-CPT) carries. The discrete symmetries as orientation: C, P, and T as the orientation reversals of the three real bulk factors — the fiber circle, the spatial slice, and the causal clock — with antiunitarity exactly where T sits (T-P5-1); the CPT theorem as orientation bookkeeping (T-P5-2); the self-contained re-proof of the circle/clock/handshake suite (T-P5-A/B/C) with the Wick quartet (T-P5-B1); the four-endowment definition of time consolidated in its Part IX (the custody statement of §7 points there); and, on the matter side, the flavored leptogenesis chain fed by GG-A9-SM's ledger phases and delivered to GG-A10-Cosmos's η_B chain, with the sign carried by the Majorana parity $\alpha_{31} = \pi$. Grade, stated honestly: the mirrors and CPT are derived at the quasi-free grade; the matter throughput is derived-conditional on its named finite-temperature hypothesis (H-phigeo-1). Carries no Principal Theorem of the present paper.

27.8 Bridge to the Predictions Branch (P1, C1, ...)

The Predictions Branch carries specific empirical falsifiers, each with a registered claim contract (instrument, calibration, timescale, kill criterion) per POS-7 MF. The branch is extensible: P-numbered papers carry particle-physics predictions, C-numbered papers carry cosmology predictions, with further labels reserved for future predictions.

What GG-P1-KK (Arisaka, 2026, P1-KK) carries. The non-spatial Kaluza-Klein lock cluster — RG-scale resonances of the RG-scale throat, not a spatial extra dimension — at $M_{\text{lock}} \approx 3.85\,\text{TeV}$, with explicit LHC and future-collider falsifiers. Any verified collider deviation from the predicted resonance pattern at the 5σ level falsifies T4 + T6 jointly.

What GG-P2-N3 (Arisaka, 2026, P2-N3) carries. The three-leg derivation of the family number: exactly three fermion generations, from a CP-violation lower bound, a GDOS Morse/budget upper bound, and a codebook cross-check — with the conditioning (the coupling clause and integrality lemma L-INT of that paper, at premises shared with the Constitutional Born Theorem) declared at every level. A verified fourth generation falsifies the derivation outright.

What GG-P3-Electron (Arisaka, 2026, P3-Electron) carries. The six oldest questions about the electron — identity with its measured values, absolute stability, the two excited copies, the positron as conjugate readout, pointlikeness, and the response to fields — closed as six faces of one fact: the electron is the unique ground state of its boundary stratum. Written as a review and gateway; imports GG-P2-N3's $N = 3$ with its fences verbatim. Any observed electron decay, substructure at any scale, or a fourth lepton generation falsifies it.

What GG-P6-Proton (Arisaka, 2026, P6-Proton) carries. The proton as the GGA of the baryonic stratum: its exact mass and zero width, its charge equal and opposite to the electron's, its spin, and above all its stability — baryon number carried not as a bookkeeping label but as a winding of the compact geometry, written by the same twist that breaks the unified gauge symmetry and splits the Higgs multiplet, so that the decay the grand unified theories insisted on is forbidden by the geometry rather than merely unobserved. Eleven questions the proton poses, closed as faces of one fact, every import at its proved grade and every kill criterion stated. A single verified proton decay falsifies it.

What GG-C1-Kaxion (Arisaka, 2026, C1-Kaxion) carries. The kaxion oscillation $\Delta\nu/\nu = 1/35$ in the dark-matter sector, with explicit haloscope and microwave-cavity falsifiers. Any verified discovery at $\Delta\nu/\nu \neq 1/35$ falsifies the OGN-5 ledger.

What GG-C2-Hubble (Arisaka, 2026, C2-Hubble) carries. The Hubble tension read as geometry: the two measured Hubble constants as the two ends of one six-dimensional geometric corridor, with the corridor's endpoints fixed by the same 6D bulk that fixes the lock scale.

What GG-C3-BH (Arisaka, 2026, C3-BH) carries. Black-hole entropy under GG-Theory: the horizon as an OGGEP port, with the exact Bekenstein–Hawking coefficient $A/4$ obtained from induced gravity — the cohort's strong-gravity anchor.

27.9 Bridge to the White-Paper Branch (W1, W2)

On the map's right flank stand two synthesis papers. They are the mirror of the Foundations Branch in the literal sense: that flank feeds the spine, this one reads it. Neither derives anything new; each carries every result at its parent's declared grade, and each says so of itself. They are addressed to a physicist who wants to know what the cohort amounts to without reading all twenty-two papers.

What GG-W1-Symmetry (Arisaka, 2026, W1-Symmetry) carries. The *diachronic* reading: the century of symmetry and conservation walked in the order it was found — Noether's two theorems, the Bianchi identity, Wilson's loops, the Green–Schwarz mechanism, Hopkins–Singer quantization — and the conviction that symmetry causes conservation loosening at each step, until what remains conserved is an integer with nowhere to move. The program is placed at the end of that sequence, at declared grades, with its payout set beside the measurements. Its capstone is the determinism triad: symmetry breaking re-read as symmetry *reading*.

What GG-W2-Holonomy (Arisaka, 2026, W2-Holonomy) carries. The *synchronic* reading: one exact and elementary statement — a holonomy requires a closed loop, and the interval fiber has none, so everything on the circle is quantized, protected and reversible while nothing on the interval can be — followed to sixteen of the questions physics has not closed, from what happens when a measurement happens to what became of the information that fell into a black hole. The paper closes with the named, dated measurements on which six of the sixteen treatments die outright, and with how the other ten are exposed through the ledger they share.

27.10 Cross-paper coherence map

Table 6 pins each Principal Theorem Tk to the canonical theorem location in the companion paper where its proof actually lives. This is the master audit reference for the GG-Theory series.

Audit trail. Each row of Table 6 has been verified against the actual companion-paper PDF named in the row. In particular, the GG-A2-GG6 internal theorem numbering, written here in the cross-paper form Tn-GG6, is: T1-GG6 (dimensional minimality of the bulk), T2-GG6 (canonical metric of GG-6), T3-GG6 (six forces with three Abelian invariances — the gauge-group theorem), T4-GG6 (BI-6 coefficient vector), T5-GG6 (single-tensor anomaly factorization $I_8 = \frac{1}{2}X_4 \wedge X_4$), T6-GG6 (the OGN-5 Diophantine cascade), T7-GG6 (BRST consistency and homogeneous Slavnov–Taylor identity), T8-GG6 (Arisaka equation and Quadruple Gauge Locking); the GG-A5-GDOS internal theorem numbering uses local labels T-GDOS-1 through T-GDOS-11, printed as T1–T11, which match by construction those of the present coherence map; the GG-A6-GRIP internal numbering uses local labels T-GRIP-1 through T-GRIP-5, printed as T1–T5, for the four pillars and the synthesis; the GG-A7-Qi4 internal theorem numbering is section-prefixed and runs continuously through that paper, so its four pillars occupy Parts III–VI (§§11–49) with main theorems at 12.x–15.x (Qi-QUA), 22.x–27.x (Qi-EP), 33.x–36.x (Qi-CON), and 42.x–47.x (Qi-HAL). Each row names the theorem's content as well as its number, so a renumbering in a companion shows up as a mismatch a reader can see rather than as a silently wrong pointer.

Table 6: Cross-paper coherence map for the eleven Principal Theorems. Each row records the theorem name and the canonical companion-paper location where its proof lives. None is proved inside the present paper; the constitution names them and points the reader downstream.

Tk	**Theorem name**	**Proof location**
T1	Locked Equivalence	GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 8 (Arisaka equation and Quadruple Gauge Locking on the composite $\mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$ connection)
T2	Operational Closure	GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Theorem T2 (Exact Bulk-to-Boundary Reduction, Nakajima-Zwanzig form)
T3	Anti-Landscape Selection	GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 3 (Six forces with three abelian invariances — the unique gauge group $\mathrm{Spin}(1,5)\times\mathrm{SU}(5)\times\mathrm{U}(1)_B\times\mathrm{U}(1)_{Qi}$ forced by AX-2 + AX-4 + POS-1 + POS-3, eliminating all landscape alternatives)
T4	6D bulk Existence	GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 1 (dimensional minimality of the bulk: $\mathcal{M}_6 = M_4 \times I_r \times S^1_\theta$) + Theorem 2 (canonical metric $ds_6^2 = \mathrm{e}^{-2r}\eta_{\mu\nu}\, dx^\mu dx^\nu + dr^2 + d\theta^2$)
T5	BI-6 Four-Component Anomaly Identity	GG-A3-BI6 (Arisaka, 2026, A3-BI6), Theorem 8.1 (the OGN-5 trace-ratio theorem: the SU(5) trace ratio $\mathrm{Tr}(B_0^2)/\,\mathrm{Tr}(Y_0^2) = (L-N)/L$ fixes the abelian fraction to exactly 2/5 at $(N,L) = (3,5)$), completed globally by Theorem 6.2 (complete anomaly freedom of BI-6 through the Wu-Chern-Simons / Hopkins-Singer differential-cohomology lift), plus the redundant cross-check at GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 4 (BI-6 coefficient vector $(a,b,c,d) = (1,-1,-2/5,-2/5)$)
T6	OGN-5 Ledger as Bulk Output	GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 6 (the OGN-5 Diophantine cascade fixes $(M,N,L;J,K) = (1,3,5;7,35)$ as a five-step integer pinning forced by AX-4 + POS-6)
T7	4D Quantum Mechanics	GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Theorem T7 (QM as boundary projection: Born rule, projection postulate, Bell, Stern-Gerlach, Aspect 1982 + Hensen 2015) plus seven sub-theorems
T8	4D General Relativity	GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Theorem T8 (GR as boundary projection: modified TOV, Schwarzschild + Kerr limits, equivalence principle) plus seven sub-theorems
T9	4D Quantum Field Theory	GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Theorem T9 (QFT as boundary projection: BRST cohomology, Slavnov-Taylor identities, anomaly Ward identity) plus eight sub-theorems

continued on next page

Tk	Theorem name	Proof location
T10	Gi-4 Pillars	GG-A6-GRIP (Arisaka, 2026, A6-GRIP), Theorems T1 (TGG existence, uniqueness, and Master Conservation), T2 (CCI closure forces OGN-5), T3 (GFF Morse-positivity), T4 (GRIP cascade closure: DGI → GSSB → GA), and T5 (constitutional equivalence of the Gi-4 pillar system and the GG-Constitution plus BI-6)
T11	Qi-4 Pillars	GG-A7-Qi4 (Arisaka, 2026, A7-Qi4), four-pillar main theorems located in Parts III–VI (§§11–49): Qi-QUA pillar (Theorem 12.2 rank-one inflow, Theorem 14.3 no-new-parameter, Theorem 15.3 natural-unit equivalence); Qi-EP pillar (Theorems 22.1, 23.1, 24.1 for the PLT, MEPP, and FEP gauges, with the common-origin theorem at Theorem 27.1); Qi-CON pillar (Theorem 33.1 operational conformality, Theorem 36.1 two-knee spectrum); Qi-HAL pillar (Theorem 42.2 MePMoS, Theorem 44.2 frequency-independent HAL, Theorem 47.1 Qi-HAL universality)

The axiomatic bargain offered by the GG-Theory program is exactly this: eleven theorems, eleven companion-paper homes, every pointer auditable. If a single row of Table 6 fails contact with experiment, the constitution upstream falls.

The Geometric Universal Five Constants (GU-5): c, G_N, $\hbar$, k_B, $\mathsf{Q_B}$

One synoptic theorem deserves a name of its own. The five universal dimensional conversion factors of physics — c, G_N, $\hbar$, k_B, $\mathsf{Q_B}$ — are not free parameters of GG-Theory; each is a calculable geometric or boundary-projected datum of the 6D bulk. We collect this synoptic claim as the *Geometric Universal Five Constants theorem*, T − GU5, with each constituent pinned to its primary companion paper:

Theorem 1 (T − GU5: Geometric Universal Five Constants)**.** *Under the GG-Constitution, the five universal dimensional conversion factors are derived secondary quantities of the 6D bulk geometry and its boundary projection, with primary derivations as follows:*

- *c — conversion factor of the $(1, 3)$ Lorentzian signature on $\partial\mathcal{M}_6 = \mathcal{M}_4$, fixed by the canonical metric of (Arisaka, 2026, A2-GG6, Theorem 2 (canonical metric)).*
- *$\hbar$ — conversion factor of the compact S^1_θ topology, fixed by Kaluza–Klein integer mode quantization in the 6D bulk (Arisaka, 2026, A2-GG6, Theorem 1 + topological S^1 section).*
- *G_N — scale-curvature coupling of the radial interval I_r, expressed as the overlap integral (Arisaka, 2026, A5-GDOS, Theorem T8.2 (Newton constant)) of the scale-profile metric of (Arisaka, 2026, A2-GG6, Theorem 2).*
- *$\mathsf{Q_B}$ — energy–information Arisaka constant $\mathsf{Q_B} = (2/5)E_{\mathrm{Ry}}/K$, the conversion factor between energetic and gauge-count currents on the IR boundary, derived in (Arisaka, 2026, A7-Qi4, §9, T-QUA.2).*

- k_B — *Bekenstein–Hawking thermodynamic conversion factor of the IR-boundary surface gravity, fixed by the scale profile e^{-K} with $K = 35$ (Arisaka, 2026, A4-Euclid, §25 (k_B derived)).*

Together with the two topological constants $\{e, \pi\}$ of (Arisaka, 2026, A4-Euclid, §26), the Pentad supplies the full dimensional and arithmetic basis from which every dimensionful scale of GG-Theory (Planck, GUT, lock, electroweak, Rydberg, biological, cosmological-constant) is forced, given the single overall unit scale, set by G_N (with M_6 derived from it).

The Pentad is synoptic, not new: every conversion factor it names is derived in a primary companion paper, and the present subsection only collects them under a single theorem label so that downstream papers can cite "T − GU5" as the closure statement of the conversion-factor reconstruction. The closing remark of GG-A4-Euclid (Arisaka, 2026, A4-Euclid, §28 Master Derivation Table) provides the full numerical-values table; the present theorem is the axiomatic statement that closes the table.

27.11 Minimum reading path for evaluators

A reader who wishes to assess the central claims of the cohort framework on a first pass should follow a focused reading path rather than attempting the full cohort inheritance at once. The recommended sequence is:

1. This paper (GG-A1-Constitution) for the four axioms, the seven postulates, and the constitutional classification of twentieth-century physics (Part V).
2. GG-A2-GG6 (Arisaka, 2026, A2-GG6) for the uniqueness theorem of the 6D bulk and the OGN-5 Diophantine forcing; this is the load-bearing technical paper, and the entire cohort depends on its uniqueness arguments holding up.
3. GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Part III for the T7.1–T7.7 derivation of the textbook QM postulates (Born rule, Lüders projection, decoherence, einselection, Bell–CHSH violation) from AX-3 OGGEP together with POS-4 CP; this is the load-bearing technical paper for the "measurement problem is solved" claim.
4. GG-A9-SM (Arisaka, 2026, A9-SM), the worked chapter for one specific Standard-Model parameter (any one of the 28) as an explicit example of the 28-to-0 collapse claim.

A reader who completes these four documents has the necessary scaffolding to form a real opinion about whether the constitutional program is correct. The remaining cohort papers (GG-A3-BI6, GG-A4-Euclid, GG-A6-GRIP, GG-A7-Qi4, GG-A8-QM, GG-A10-Cosmos, and GG-A11-Origin, the last of these in preparation) supply the depth and breadth of consequences but are not strictly required for first-pass evaluation.

27.12 Consolidated falsifier table: numerical predictions and kill thresholds

Table 7 consolidates the sharpest numerical predictions issued by the GG-Theory program. Each row records a global falsifier identifier F-Constitution-k, the constitutional source (which axiom/postulate combination forces the prediction), the proof location in the cohort, the predicted value, the currently best-measured value, the comparison mode — a pull in sigma where the comparison yields a number, and otherwise the kind of check the entry carries — the pre-declared kill threshold, and the experimental status as of 2026. Indeed, the strength of the constitution is best measured not by what it explains but by what it would have to give up if any one row's kill criterion were triggered.

Table 7: Consolidated falsifier table. The sharpest numerical predictions of the GG-Theory program, with proof location, pre-declared kill threshold, and current experimental status. Each entry is headed by its global falsifier identifier and is a POS-7 MF claim contract in the canonical four-tuple form. *Mode* records how the prediction is being compared with data: a pull in sigma where the comparison yields a number, and otherwise the kind of check the entry carries, in the sense fixed immediately after the table.

Source	Predicted	Observed	Mode	Kill threshold	Status (2026)
F-Constitution-1: GUT-scale unification $E_{\rm GUT}$					
OGN + 6D bulk; GG-A2-GG6	$E_{\rm Pl}\, e^{-2\pi} \approx 2.28 \times 10^{16}$ GeV	Inferred from α_i flow extrapolation	Consistency	Failed unification at one loop falsifies	Forward audit (cohort)
F-Constitution-2: KK lock-cluster $M_{\rm lock}$					
OGN-5 + 6D bulk; GG-A2-GG6, GG-A9-SM, GG-P1-KK	$(1/2)\, M_{\rm Pl}\, e^{-35} \approx 3.85$ TeV	No resonance yet at this mass; LHC Run 3 + HL-LHC search ongoing (Particle Data Group, 2024)	Conditional	Registered 5σ absence at HL-LHC, or 5σ resonance at $\neq M_{\rm lock}$	Active LHC search
F-Constitution-3: Electroweak vev v					
OGN + bulk; GG-A9-SM	≈ 246 GeV	246.220 ± 0.001 GeV (Particle Data Group, 2024)	Postdiction audit	Verified deviation $> 5\sigma$ from the rational structural derivation	Verified
F-Constitution-4: Cosmological matter fraction Ω_m					
OGN-5 + bulk; GG-A10-Cosmos	$1/\pi \approx 0.31831$	0.3153 ± 0.0073 (Planck 2018 (Planck Collaboration, 2018))	$\sim 0.3\sigma$	Registered 5σ deviation from $1/\pi$ in any next-generation cosmology dataset at resolution $\sigma_{\Omega_m} \leq 0.003$	Consistent; CMB-S4 / LiteBIRD / DESI next-gen test
F-Constitution-5: Cosmological-constant scale m_Λ					
OGN + bulk; GG-A10-Cosmos	≈ 6 meV	Consistent with $\Lambda \approx 1.1 \times 10^{-52}$ m^{-2} (Planck Collaboration, 2018)	Postdiction audit	Verified deviation $> 5\sigma$ from the predicted neutrino-scale matching	Consistent (CC sign + scale)

(continued)

Source	Predicted	Observed	Mode	Kill threshold	Status
F-Constitution-6: Cosmological baryon fraction Ω_b					
OGN-5 + bulk; GG-A10-Cosmos	$1/(2\pi^2) \approx 0.05066$	0.0493 ± 0.0006 (Planck 2018)	$\sim 2\sigma$	Registered 5σ deviation in any next-generation BBN / CMB combined fit	Consistent at $\sim 2\sigma$
F-Constitution-7: Kaxion oscillation $\Delta\nu/\nu$					
OGN-5 (integer $35 = K$); GG-A10-Cosmos, GG-C1-Kaxion	$1/35 \approx 0.02857$	Not yet registered	Forward	Registered narrow peak at $\Delta\nu/\nu \neq 1/35$ at 5σ over $10\sigma_\nu$ control region	Active haloscope search (ADMX-class)
F-Constitution-8: Three generations					
OGN-5 ($N = 3$); GG-A2-GG6, GG-P2-N3	Exactly three fermion families	Three observed (Particle Data Group, 2024)	Verified	Discovery of a fourth admissible generation falsifies $N = 3$	Verified
F-Constitution-9: BI-6 trace-ratio lock					
POS-3 AF + POS-6 OGN + bulk; GG-A3-BI6	$\lvert a/c\rvert = \lvert a/d\rvert = 5/2$, $(a, b, c, d) = (1, -1, -2/5, -2/5)$	Implied by SM hypercharge assignments via descent; consistency check (Arisaka, 2026, A3-BI6)	Audit	Discovery of a fifth admissible anomaly polynomial structurally inequivalent to BI-6	Internally consistent; downstream audit
F-Constitution-10: Reality of the bulk category (cohort alias F-Real-1)					
AX-4 MSMF + L-Constitution-1 (candidate); GG-P4-Real, GG-P5-CPT	Every observed i is the boundary reading of the one derived quarter-turn J: no fundamental non-geometric CP phase; one shared i; no quaternionic Born residue	No anomaly registered: unshared-real alternative excluded (Renou et al., 2021); three-path Sorkin residue consistent with zero (Sinha et al., 2010)	Audit	A fundamental CP phase resisting geometric expression after the GG-A9-SM QD freeze; verified unshared-i interferometry; a registered 5σ quaternionic-direction Born deviation	Forward audit (candidate grade; §8.5)

The classification of the *Mode* column follows the cohort's internal conventions: *Forward* predictions await first experimental registration; *Verified* predictions have been empirically confirmed and now serve as anchor data; *Audit* predictions are internal consistency checks that downstream cohort papers must satisfy; *Postdiction-audit* predictions are historically known quantities that the cohort derivation must *retro*produce; *Conditional* predictions sit at the boundary of current experimental sensitivity and become Forward or Verified as data accumulates. The pre-declared kill threshold of every row is the constitutional commitment that POS-7 MF extracts from the corresponding theorem: a verified violation of any row above would collapse one or more clauses of the constitution upstream.

27.13 Worked calculation chain: from OGN-5 to the kaxion oscillation $\Delta\nu/\nu = 1/35$

To illustrate how a single numerical prediction descends from the constitution into the cohort, we walk one chain end to end: the kaxion oscillation $\Delta\nu/\nu = 1/35$ of GG-C1-Kaxion (Arisaka, 2026, C1-Kaxion). No derivation is performed inside the present paper; each step names the relevant constitutional clause and the proof location in the cohort.

1. AX-2 GGEP together with POS-3 AF, POS-5 RG, and POS-6 OGN forces the 6D bulk metric $ds_6^2 = e^{-2r}\eta_{\mu\nu}dx^\mu dx^\nu + dr^2 + d\theta^2$ with the four-factor composite gauge group $G_{\text{tot}} = \text{Spin}(1,5) \times \text{SU}(5) \times \text{U}(1)_B \times \text{U}(1)_{Qi}$ (uniqueness theorem T4 of GG-A2-GG6 (Arisaka, 2026, A2-GG6)).
2. POS-6 OGN on the bulk forces the OGN-5 integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ as the unique lexicographic maximum of the Diophantine system $K = LJ = M^2 + N^2 + L^2$ with chirality count $J = 2N + 1$, compatible with the four-component anomaly polynomial of T5 (theorem T6 of GG-A2-GG6).
3. AX-2 GGEP on the compact θ-circle of the bulk admits a pseudo-Nambu-Goldstone field — the kaxion — whose mass m_k is set by the $\text{U}(1)_{Qi}$ holonomy and the OGN-5 lock length $K = 35$; specifically, m_k is fixed by that holonomy and that lock length — not by the $M_{\text{lock}}^2/M_{\text{Pl}}$ combination, which sets the cosmological-constant scale some five orders of magnitude higher (derived in GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos), Theorem T9).
4. Under cosmological boundary conditions the kaxion field oscillates around the bulk holonomy minimum with a frequency shift $\Delta\nu/\nu$ that is the OGN-5 integer fraction $1/K = 1/35$, forced by the period of the θ-circle and the lock-length quantization (worked example in GG-C1-Kaxion (Arisaka, 2026, C1-Kaxion)).
5. POS-7 MF then requires the prediction to compile to a registered measurement contract: a haloscope-style microwave cavity tuned to the kaxion mass, with a pre-declared kill criterion of 5σ registered disagreement with $\Delta\nu/\nu = 1/35$ over a $10\sigma_\nu$-wide control region (see Part III, §20 and GG-C1-Kaxion).

The chain has five steps. Step 1 lives in GG-A2-GG6; step 2 lives in GG-A2-GG6; step 3 lives in GG-A10-Cosmos; step 4 lives in GG-C1-Kaxion; step 5 lives both in Part III of the present paper and in GG-C1-Kaxion. After all, the cohort's structural integrity is exactly this: a five-step chain from the constitutional integers $(1, 3, 5; 7, 35)$ to a μeV cavity signal that an experimenter can register or fail to register.

Closing remarks on Part IV

The handoff is complete. Every claim this document makes now has an address — a named theorem, in a named paper, at a named number.

It is fair to ask whether that is a virtue or an evasion, and the question deserves a direct answer rather than a slogan. It is an evasion if the addresses are vague, if they drift as the companions are revised, or if following one leads to a paper that forwards you somewhere else again. It is a virtue only if the pointers are exact and stay exact. We take this seriously enough that the coherence map was rebuilt against the companion papers themselves rather than from memory, and a reader who finds a row that does not resolve should treat that as a real defect and not a typographical one.

The wider principle is one that engineers know better than physicists. A specification and an implementation are different documents, and confusing them damages both. A specification long enough to contain its implementation cannot be read as a specification; an implementation that repeats its specification drifts out of agreement with it. Physics has traditionally written the two together, in the same paper, in the same voice — which is part of why the rules ended up unwritten. They were never given a document of their own.

There is a cost, and we would rather state it than let a reader discover it with irritation. Someone who wants to check a single number in the consolidated falsifier table will have to open at least one companion paper, and possibly two. That is a real demand on a reader's time, and no amount of good cross-referencing makes it free. What we can promise is that the demand is finite and mapped: the minimum reading path in this Part names four documents, not twenty-two, and the falsifier table names the experiment rather than asking you to trust the derivation.

There is also something the map reveals that no single paper does. Reading down the coherence table, one sees the same five integers turning up in the anomaly coefficients, the generation count, the electroweak scale, the recombination era, and the dark-matter oscillation frequency. Whether that recurrence is a discovery or a coincidence is exactly what the cohort is for. But the recurrence itself is visible only from here, in the index — which is a reason indexes are worth reading.

Part V now asks a different question. Instead of where our own proofs live, it asks where everyone else's theories live, and finds that the same four axioms sort them.

Part V
The Constitutional-Axiom Classification of 20th-Century Physics

General Relativity, Gauge Theory, String Theory, AdS/CFT, Quantum Mechanics, the Standard Model, and ΛCDM as Theorems of Axiom Subsets

Here is the move this Part makes, and it is worth stating plainly before the machinery arrives.

The usual way to compare physical theories is to ask which one is right. That question is often unanswerable, because rival frameworks tend to agree wherever experiment has actually reached. So we ask a different question: *which of the four axioms does each framework quietly assume?*

The answer sorts twentieth-century physics into four layers, and the sorting is not a matter of taste. Take AX-1 alone and you have special relativity — causality and a speed limit, nothing more. Add AX-2 and geometry becomes a carrier of forces: general relativity, Yang–Mills theory, and the whole classical-topological backbone on which string theory and AdS/CFT are built. Add AX-3 and observation enters as a projection, which is where quantum mechanics, statistical mechanics, the fluctuation theorems, black-hole thermodynamics and the free-energy principle of theoretical neuroscience all turn out to live — four communities that rarely read one another, sharing one axiom. Add AX-4 and the free parameters have to go.

What makes this a classification rather than a filing system is that it predicts silences. A framework standing on the second layer has no operational content, so it cannot say when a measurement happens — and, historically, it does not. A framework standing on the third has no selection principle, so it cannot say why the constants take the values they do — and it does not. What a theory *cannot* say is as diagnostic as what it can, and the missing axiom tells you which silence to expect.

We state the tower formally, walk each layer in a paragraph, print a master ledger locating every major framework, count the vacua the classification implies, and close with the case that superstring theory cannot rise past the second layer without adopting the axioms it currently declines.

28 The central structural claim, stated once

Statement. Every major theoretical-physics framework of the twentieth century is a theorem of a particular subset of the four GG-Constitution axioms applied to a particular bulk solution; the framework's strengths and limitations are direct consequences of which axioms it implicitly uses and which it lacks.

This is not a refutation of any historical framework. It is a *structural location* of each framework inside a single constitutional tower. Each historical theory correctly used the axiom subset it implicitly invoked; each left silent exactly the questions that required the missing axioms. The classification we are about to develop is the structural map.

Indeed, this Copernican reframing does not contradict the historical derivations; it locates them. Just as Riemann's nineteenth-century geometry was correctly understood as pure mathematics for sixty years before Einstein identified the physical setting (general relativity) in which it became operative, the twentieth-century geometric edifice — the Bianchi identities, the Green–Schwarz mechanism, the modular bootstrap, the AdS/CFT correspondence, the holographic principle, the dualities — has been correctly developed by the superstring community for forty years without recognition of the constitutional setting (the GG-Constitution with various axiom subsets) in which the machinery becomes operative. The present Part identifies that setting.

The technical derivation chain that backs each row of the classification is developed in full detail in GG-A5-GDOS (Arisaka, 2026, A5-GDOS, Part VIII). The present Part restates the classification in a form a reader of the constitution itself can audit at first encounter.

29 The constitutional tower: a formal statement

The four axioms of the GG-Constitution form a strict logical tower: each axiom presupposes the previous and adds new content. AX-1 requires a manifold with a causal structure. AX-2 requires AX-1 plus a bulk gauge bundle unified with the geometry. AX-3 requires AX-1 + AX-2 plus the operational dictionary. AX-4 requires AX-1 + AX-2 + AX-3 plus the uniqueness principle.

We denote the four active-axiom subsets by their natural names, and attach to each the natural *stratum* index that aligns with the constitutional axiom it activates:

- **Stratum 1** = {AX-1} — the LC level (local causality alone).
- **Stratum 2** = {AX-1, AX-2} — the GGEP-closed level (geometry-gauge equivalence on a closed bulk).
- **Stratum 3** = {AX-1, AX-2, AX-3} — the OGGEP-open level (operational/open extension to a finite-information boundary observer).
- **Stratum 4** = {AX-1, AX-2, AX-3, AX-4} — the Full-Constitution level (the full axiom set, forcing the unique integer OGN-5 ledger and zero free continuous parameters in the bulk theory).

Each Stratum-N activates Axiom AX-N, and a framework that implicitly uses axiom subset {AX-1, . . . , AX-N} sits at Stratum N. The Stratum number and the highest activated Axiom number are deliberately aligned so that the classification reads off any diagram by inspection.

Why subsets are physically meaningful. A natural objection: *the GG-Constitution is a constitution; one either accepts all four axioms or none; why is it meaningful to ask what subsets produce?* Roughly speaking, the answer is that the historical twentieth-century theories are precisely the answers to that question, asked implicitly. When string theorists postulate that geometry and gauge unify on a 10D worldsheet but do not address the operational projection to a finite-observer boundary, they are implicitly using GGEP-closed and not OGGEP-open. When QM-foundations researchers postulate the Born rule but accept that string-theoretic bulk structures are someone else's problem, they are implicitly using OGGEP-open but not invoking the bulk content that AX-2 forces. The historical theories are the natural specializations of the constitution to specific axiom subsets, and they reveal the structure of the constitution by what each takes as operative and what each leaves silent.

30 The constitutional flowchart

The single most useful visual orientation for the rest of this Part is the constitutional flowchart of **Figure 10**, overleaf in landscape orientation. Each Stratum band on the right is aligned with the constitutional axiom on the left that activates it: AX-N activates Stratum N for $N = 1, 2, 3, 4$. Each cell within a band names a historical framework that the cohort framework relocates as a theorem of that stratum. The cohort framework itself (GG-Theory, cyan band at the bottom) is the unique theory that explicitly activates all four axioms and so admits the full theorem class.

Figure 10 (next page, in landscape orientation).

The comprehensive flowchart on the following page presents the logical cascade from the four-axiom GG-Constitution (far left) to the entire family of nineteenth- and twentieth-century theoretical physics frameworks. Each axiom on the left activates the Stratum band of the same number on the right. *Stratum 1* (yellow, $\{$AX-1$\}$) holds the frameworks that need only local causality: special relativity (1905) and classical electrodynamics (1865). *Stratum 2* (orange, $\{$AX-1, AX-2$\}$; GGEP-closed) holds the geometry-gauge family descended from Bianchi 1902 — general relativity (1915), Yang–Mills (1954), the Green–Schwarz mechanism (1984), superstring theory (1984+), AdS/CFT (1997), holographic dualities (1993+), and anomaly cancellation (1984). *Stratum 3* (green, $\{$AX-1, AX-2, AX-3$\}$; OGGEP-open) holds the three siblings of openness: the quantum-mechanics family with the Born rule and Bell-inequality violations, the classical-thermodynamics family with the Friston free-energy principle, and the black-hole family with the Page curve and the islands formula. *Stratum 4* (teal, $\{$AX-1, AX-2, AX-3, AX-4$\}$; Full-Constitution) holds the frameworks that the integer OGN-5 ledger forces: the Standard Model (1967–78) with its 28 parameters collapsed to zero, ΛCDM (1998+) with $\Omega_m = 1/\pi$, and the cohort cascade (2026) from quarks to consciousness. At the bottom of the figure, the cohort framework GG-Theory is the unique theory that explicitly activates all four constitutional axioms; the three application papers (GG-A9-SM, GG-A10-Cosmos, GG-A11-Origin) operationalize the constitutional output into the SM parameters, the cosmological inventory, and the quarks-to-consciousness identity cascade. The L-shape link on the left signals the constitutional source ⇔ derived theory relation between the GG-Constitution (far left) and GG-Theory (bottom center): the constitution defines the theory, and the theory articulates the constitution.

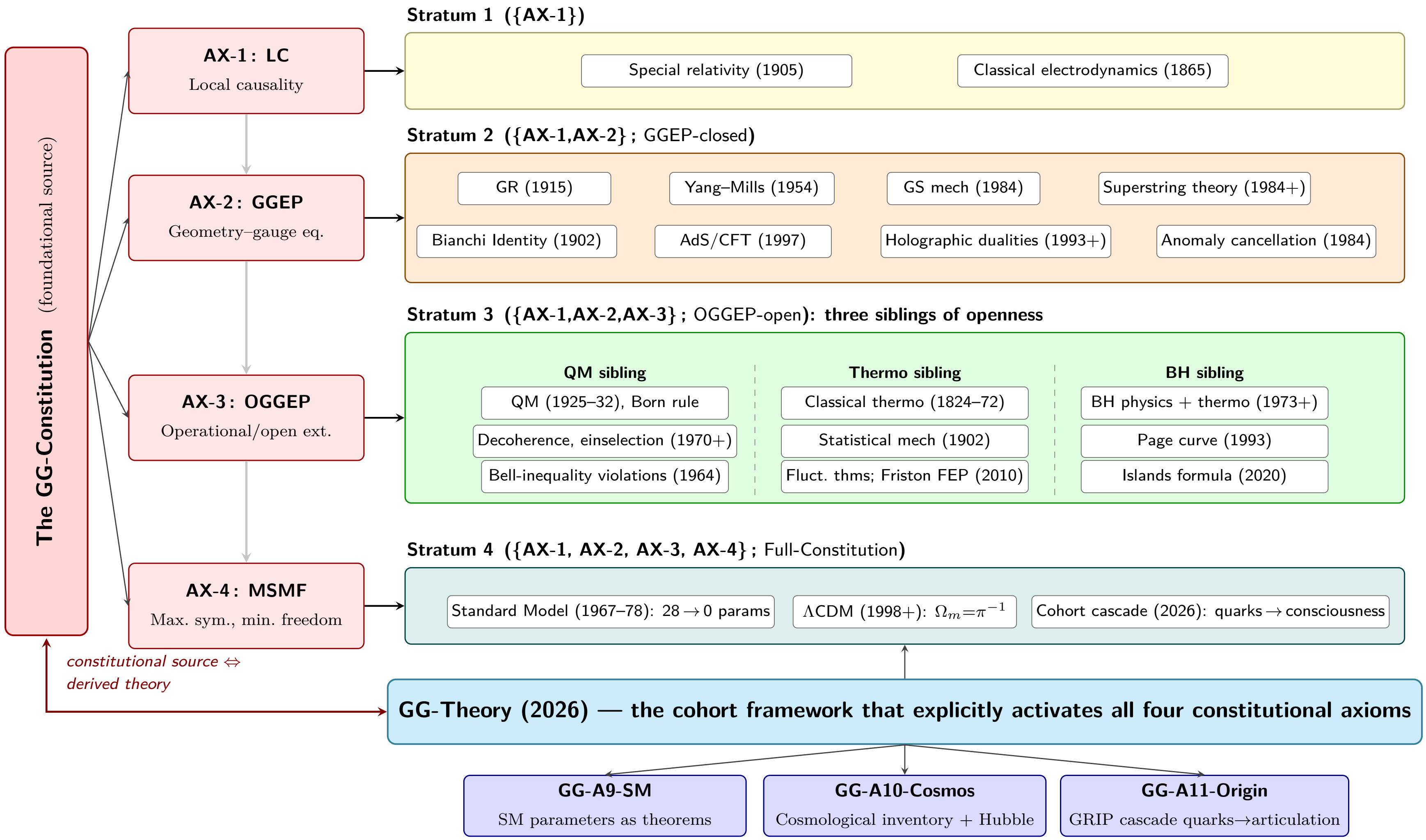

Figure 10: The constitution drawn as a flowchart. Each framework of twentieth-century physics enters at the level of the axioms it implicitly uses, and the branches descend as axioms are added: one axiom gives special relativity, two give the geometric machinery of general relativity and gauge theory, the third adds the boundary coarse-graining that quantum mechanics and thermodynamics share, and the fourth removes the freedom that remains. What each branch *cannot* say is the content of the chart — a missing axiom is a prediction about which questions a framework will leave open, not merely an omission — and the extended description on the preceding page reads the chart row by row, naming for each stratum what its occupants are unable to express.

31 Walking the tower: each stratum in one paragraph

Stratum 1 ({AX-1}): special relativity and classical electrodynamics. At Stratum 1, the only constitutional content is local causality. Special relativity and classical electrodynamics live here. Local Lorentz transformations, $E = mc^2$, Maxwell's equations on Minkowski space, the radiation field as a propagating wave: all follow from AX-1 together with the choice of a flat manifold. What Stratum 1 cannot deliver is gravity (which requires the geometric content of AX-2), the quantum content of measurement (which requires AX-3), or any unique parameter selection (which requires AX-4).

Stratum 2 ({AX-1, AX-2}, GGEP-closed): general relativity, Yang–Mills, string theory, AdS/CFT. At Stratum 2, the constitutional content extends to the geometry-gauge equivalence principle. General relativity is what GGEP-closed produces when the composite connection reduces to the Levi–Civita connection alone; Yang–Mills is what it produces when the connection reduces to a Lie-algebra-valued gauge field; superstring theory is the GGEP-closed content applied to a 10D bulk with extended-object dynamics; AdS/CFT is the GGEP-closed duality between bulk AdS and boundary CFT in the same axiom subset. Remarkably, the Green–Schwarz modified Bianchi identity — conventionally presented as a string-theoretic achievement — is a theorem of AX-2 applied to a bulk with appropriate dimension; the constraint itself was always geometric and descended from Bianchi 1902 (Bianchi, 1902, Green and Schwarz, 1984). Strings supplied one physical scenario in which the constraint had to be satisfied, but the constraint's logical status was never string-dependent. What GGEP-closed cannot deliver is the quantum content of measurement (no AX-3, hence no Born rule, no Lüders projection, no decoherence as theorems; the measurement problem remains structurally unaddressed) and no unique vacuum selection (no AX-4, hence the $\sim 10^{500}$ flux landscape of the Bousso–Polchinski / Douglas–Kachru count).

Stratum 3 ({AX-1, AX-2, AX-3}, OGGEP-open): quantum mechanics and the three siblings of openness. At Stratum 3, the operational/open extension AX-3 OGGEP becomes operative. This is the stratum at which quantum mechanics with its measurement-problem resolution becomes derivable: the chain of theorems T7-.1–T7-.7 of GG-A5-GDOS (Arisaka, 2026, A5-GDOS) derives the Hilbert-space postulate, the Schrödinger equation, the Born rule, the Lüders projection, decoherence, einselection, and Bell-inequality violation as theorems of AX-3 OGGEP acting on the bulk. The textbook QM postulates are no longer postulates; they are theorems of the operational dictionary. Two sibling families share Stratum 3: classical thermodynamics with the modern Friston free-energy principle, and black-hole physics with the Page curve and the islands formula. What OGGEP-open cannot deliver is parameter selection (no AX-4); the Standard-Model gauge group and its 28 parameters remain unconstrained by this axiom subset.

Why string theory has not solved QM foundations in forty years. *Generally speaking, this is the diagnostic core of the constitutional classification.* Within GGEP-closed (the axiom subset string theory implicitly uses), the bulk-to-boundary map is a unitary equivalence (the AdS/CFT-style duality), not a CPTP channel. Unitary maps preserve all information; they do not coarse-grain;

they do not produce probability assignments from definite bulk states. The Born rule, the Lüders projection, the decoherence-induced classicality of macroscopic outcomes — all of these require the operational coarse-graining that only AX-3 supplies. Within GGEP-closed one can compute correlation functions and check duality predictions; one cannot *derive* the QM postulates because there is no constitutional machinery for the open-system reduction. This is exactly why string theory has produced no progress on QM foundations in forty years. The framework is structurally incapable of addressing the measurement problem, not for lack of effort but because the axiom needed for the derivation (AX-3) was not in its framework. Add AX-3 to the axiom set, and the measurement problem dissolves into the chain T7-.1–T7-.7.

Stratum 4 ({AX-1, AX-2, AX-3, AX-4}, Full-Constitution): the Standard Model, ΛCDM, and the cohort cascade. At Stratum 4, the maximum-symmetry-minimum-freedom axiom AX-4 MSMF activates. This is the stratum at which the Standard Model gauge group, the 28 free continuous parameters, and the cosmological-constant scale collapse from independent dials to forced consequences of the integer OGN-5 ledger. The 28 parameters of the SM become zero free continuous parameters of the full constitution (proved in GG-A9-SM (Arisaka, 2026, A9-SM)); the ΛCDM partition $\Omega_m = 1/\pi$ becomes a forced consequence of AX-4 + POS-6 OGN (proved in GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos)); the cohort cascade from quarks to consciousness becomes an axiomatic chain (developed in GG-A11-Origin (Arisaka, 2026, A11-Origin)). This is the Full-Constitution that the GG-Theory cohort framework explicitly activates, and it is what distinguishes the cohort framework from every Stratum-2 or Stratum-3 predecessor.

32 The master classification ledger

The classification is stated cleanly as a single ledger (Table 8). Each historical framework is located by the subset of GG-Constitution axioms it implicitly uses; the content it produces and the content it leaves silent follow constitutionally. The full derivation chain that backs each row is in GG-A5-GDOS (Arisaka, 2026, A5-GDOS, Part VIII, Table 5); we restate the ledger here in a compact form for the reader of the constitution itself.

Table 8: The constitutional-axiom classification of major twentieth-century theoretical-physics frameworks. Each framework is located by the subset of GG-Constitution axioms it implicitly uses; the content it produces and the content it leaves silent follow from the missing axioms. "Stratum N" is the row of the tower at which axiom AX-N becomes operative.

Framework (year)	**Stratum**	**Content produced**	**Content left silent (missing axioms)**
Special relativity (1905)	1 (AX-1)	Lorentz transformations, $E = mc^2$, classical field theory on Minkowski.	Gravity (needs AX-2); quantum content (needs AX-3); parameter selection (needs AX-4).
Yang–Mills (1954)	2 (AX-1, AX-2)	Non-Abelian gauge theory; Lie-algebraic field-strength commutators.	Specific gauge group (needs AX-4); QM content (needs AX-3).

Table 8 continued from previous page

Framework (year)	Stratum	Content produced	Content left silent
General relativity (1915)	2 (AX-1, AX-2)	Einstein field equations; black holes; gravitational waves; cosmological expansion.	QM content (needs AX-3); G_N from integer ledger (needs AX-4).
Heterotic superstring (1984+)	2 (AX-1, AX-2)	10D anomaly cancellation; GS-modified Bianchi identity; SO(32) / $E_8 \times E_8$ gauge groups; dualities.	QM content (no AX-3); unique vacuum selection (no AX-4, hence the $\sim 10^{500}$ flux landscape).
AdS/CFT (1997+)	2 (AX-1, AX-2)	Bulk gravity = boundary CFT duality; holographic computation; Ryu–Takayanagi; viscosity bound.	QM content as theorems (no AX-3); information-coarsening projection (no AX-3); unique vacuum (no AX-4).
Standard QM (1925–32)	3 (AX-1, AX-2, AX-3) implicit	Hilbert space, Schrödinger eqn, Born rule, Lüders projection, decoherence, Bell–CHSH violation (all as *postulates*).	QM postulates as *theorems* (require explicit derivation from AX-3, supplied in GG-A5-GDOS by T7-.1–T7-.7).
Standard Model (1967–78)	4 (AX-1, AX-2, AX-3, AX-4) implicit	SU(3) × SU(2) × U(1) gauge group; three fermion generations; CKM/PMNS mixing; Higgs mechanism.	Constitutional warrant for the specific group and the 28 parameters (supplied in GG-A9-SM).
ΛCDM cosmology (1998+)	4 (AX-1, AX-2, AX-3, AX-4) implicit	Cosmological inventory; CMB power spectrum; structure formation; accelerated expansion.	Constitutional warrant for $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$ (supplied in GG-A10-Cosmos).
GG-Theory cohort (2026)	**4 explicit**	**All of the above as theorems, plus the universal-identity insight, the GRIP cascade, and the cosmos–life–mind unification of GG-A11-Origin.**	**None at the constitutional level; specific empirical predictions await the next decade of measurements.**

The diagonal structure of the table is immediate: reading top-to-bottom, each row activates more axioms than the previous, and each row produces strictly more content. The historical sequence in which the frameworks were developed is approximately the same as the constitutional sequence in which they activate axioms — a coincidence that reflects the fact that the easier physics (with fewer axioms) was discovered first. The two famous limitations of string theory — "no QM derivation" and "vacuum landscape" — sit at the Stratum-2 row of the table, exactly where the absence of AX-3 and AX-4 predicts them; both vanish at the Stratum-4 row of the cohort framework where all four axioms are explicitly invoked.

33 Quantitative consequences: the vacuum count

The most striking quantitative consequence of AX-4 MSMF is the collapse of the vacuum landscape. Stratum 1 alone admits an infinite family of Minkowski-metric choices. Stratum 2 (general GGEP-closed) admits an infinite family of bulk solutions; restricted to the 10D heterotic specialization it admits $\sim 10^{500}$ flux vacua (the Bousso–Polchinski / Douglas–Kachru landscape count). Stratum 3 (OGGEP-open) inherits the infinity; the operational dictionary adds boundary content but does not select among bulk vacua. Stratum 4 (Full-Constitution) collapses the landscape to exactly $\boxed{1}$: the unique admissible bulk that the integer OGN-5 ledger forces. This is the constitution's signature quantitative payoff: a 10^{500}-fold collapse in admissible vacua under the addition of one constitutional axiom.

34 What the classification means for the reader

For the reader who came from string theory. The constitutional classification credits the string community's forty-year mathematical achievement in full — the Green–Schwarz mechanism, the Calabi–Yau compactification framework, T-duality, S-duality, mirror symmetry, M-theory in 11D, D-branes, the AdS/CFT correspondence, the Ryu–Takayanagi formula, the viscosity bound, the modular bootstrap, the swampland conjectures — and relocates this body of correct mathematics inside the GGEP-closed stratum of the constitutional tower. The string-theoretic mathematics is correct, and the cohort framework inherits it unchanged. What the cohort adds is the constitutional reading of *where* this mathematics sits and *which* axioms its silent gaps require. The reader from string theory should hear the classification as a relocation, not as a refutation.

For the reader who came from QM foundations. For ninety years the measurement problem has been presented as the most awkward gap in physics, with every textbook closing its chapter on quantum mechanics with a hedged sentence about the role of the observer. The constitutional classification supplies a sharp diagnosis: the measurement problem is the structural symptom of working in GGEP-closed without AX-3. Add AX-3 to the axiom set, and the QM postulates become theorems (T7-.1–T7-.7 of GG-A5-GDOS), the measurement problem dissolves, and the textbook hedged sentence can be replaced with a clean derivation.

For the reader who came from the Standard Model and cosmology. The 28 free continuous parameters of the SM and the ΛCDM partition $\Omega_m \approx 0.318$ have, for fifty years, been understood as empirical inputs that the framework accommodates but does not predict. The constitutional classification supplies the missing axiom: AX-4 MSMF together with POS-6 OGN collapses the parameter count to zero free continuous parameters and forces $\Omega_m = 1/\pi$ exactly, with deviations from these predictions serving as falsifiers of the upstream axiom.

The structural payoff. Each twentieth-century framework correctly used the axiom subset it implicitly invoked; each left silent exactly the questions that required the missing axioms; once the right axiom is named, the historical gaps dissolve into chains of theorems. After all, the deepest move a foundational theory can make is to take everything its predecessors got right, locate it inside a larger constitutional picture, and use the same picture to fill the gaps the predecessors could not address. The constitutional classification is precisely that move, applied to the entire twentieth-century edifice of theoretical physics.

35 Why superstring theory cannot ascend beyond Stratum 2 — the four-fold constitutional exclusion

The Master Classification Ledger of §32 locates superstring theory in 10D and M-theory in 11D at Stratum 2 of the four-axiom tower. This closing Section makes explicit *why* the superstring framework, despite its forty-year mathematical development and despite the spectacular construction of the AdS/CFT correspondence, cannot ascend within its own terms to Stratum 3 (which adds AX-3 OGGEP) or Stratum 4 (which adds AX-4 MSMF). The four constitutional obstructions appear in Part V's classification language as follows.

Obstruction 1 — SUSY is the missing-AX-4 inflation. Supersymmetry adds ~ 100 new continuous parameters (sparticle masses, mixing angles, soft-breaking terms) to a framework whose primary purpose was to constrain a Standard Model with 28 free continuous parameters. Fifty years of accelerator search (LEP, Tevatron, LHC) and forty years of direct and indirect WIMP search have produced no evidence for superpartners at any mass scale up to ~ 2 TeV. In Part V's classification, this is the diagnostic signature of the missing AX-4 MSMF: the framework permits continuous parameter inflation precisely because the axiom that forbids it is not in the framework's axiom set. Adding AX-4 MSMF collapses the SUSY parameter space to zero.

Obstruction 2 — 10D / 11D is the missing-AX-4 dimension. The 10D dimension for the heterotic superstring and the 11D dimension for M-theory are required by anomaly-free supersymmetric consistency. The Calabi–Yau compactification program of the last forty years has been the technical attempt to stabilize the $\sim 10^{500}$ continuous moduli that the higher dimensions introduce. In Part V's classification, every dimension above *six* is missing-AX-4 freedom: the cohort minimum, derived in GG-A2-GG6 (Arisaka, 2026, A2-GG6) and proved consistent in GG-A3-BI6 (Arisaka, 2026, A3-BI6), is the 6D bulk $\mathcal{M}_4 \times I_r \times S^1_\theta$. The reduction from 10D/11D to 6D is the constitutional remedy that the missing AX-4 MSMF would otherwise leave unaddressed.

Obstruction 3 — SO(32) and $E_8 \times E_8$ are the missing-AX-4 gauge content. The 10D superstring's allowed gauge groups are 496-dimensional, with vast Yukawa-coupling matrices and free flavor parameters. In Part V's classification, the gauge-content excess is missing-AX-4: the cohort minimum gauge content, derived in GG-A2-GG6 and proved consistent in GG-A3-BI6 via the trace-ratio lock $|a/c| = |a/d| = 5/2$, is $\mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$. Every gauge factor beyond this minimum is forbidden by AX-4 MSMF. The reduction from SO(32) or $E_8 \times E_8$ to the cohort minimum is the constitutional remedy.

Obstruction 4 — operational projection is the missing-AX-3 structural content. Superstring theory inherits the von Neumann cut from textbook quantum mechanics and is structurally incapable of deriving the Born rule, the Lüders projection, decoherence, or einselection as theorems. In Part V's classification, this is exactly the missing-AX-3 diagnostic of §31: within GGEP-closed (the axiom subset string theory implicitly uses), the bulk-to-boundary map is a unitary equivalence rather than a CPTP projection, and unitary maps do not coarse-grain. Adding AX-3 OGGEP supplies the operational projection and turns the QM postulates into theorems (Part II's Remark 1, §11).

The constitutional reading. Each of the four obstructions is, in Part V's diagnostic language, a *missing-axiom symptom*: superstring theory sits at Stratum 2 because AX-3 OGGEP and AX-4 MSMF are not in its constitutional kit, and the four obstructions above are the precise structural consequences. Adding both axioms — without changing any of the Stratum-2 mathematical content the cohort inherits — promotes the framework to Stratum 4 in the more economical 6D realization that the cohort framework adopts. This is the most precise statement of what string theory does *not* deliver that the cohort framework does. We offer it here not as a refutation but as the structural location of the inheritance boundary between the string-theoretic mathematics — which the cohort credits and uses — and the constitutional content, which only the four axioms together supply. After all, a constitution is most useful when it can name not only what it adds but exactly which clauses its predecessors are missing.

Closing remarks on Part V

The tower is on the page. Every major framework of twentieth-century physics has been located by the axioms it uses, the famous limitation of each has been traced to the axiom it lacks, and the count of admissible vacua has fallen from something like 10^{500} at the second layer to one at the fourth.

We want to be careful about what has and has not been shown, because this is the Part most open to being oversold. Nothing here refutes any framework. General relativity is not wrong for standing on two axioms; it is one of the most successful theories ever written, and it stands exactly where its own assumptions put it. The claim is narrower and, we think, more interesting: each framework's characteristic silence is predictable from its position, and the prediction can be checked against a century of published work.

That is the part we would ask a skeptical reader to weigh. It would have been easy to build a classification that merely re-describes what everyone already knows. The test of whether this one is doing work is whether it says anything the practitioners did not already say about themselves — and the honest answer is that in most cases it does not tell them something new, it tells them why the thing they already knew had to be so. A framework without an operational axiom does not fail to address measurement through oversight or lack of effort. It cannot address measurement, because it has no object in its formalism that corresponds to a finite observer reading a finite record. The silence is structural, and structural silences do not yield to cleverness.

There is an older idea underneath this, and it is worth naming. We are used to thinking that a theory is characterized by its predictions. The tower suggests that a theory is at least as well characterized by its undefined terms — by the questions that cannot be posed in its language at all.

Ask general relativity when the wavefunction collapses and the question does not come out false; it comes out meaningless, because neither noun exists in the theory. What a framework cannot say is not a gap in its knowledge. It is a fact about its shape.

If that is right, then progress in physics looks a little different from the usual story. It is less a matter of finding the right answers and more a matter of enlarging the set of questions that can be asked at all — and each enlargement costs an axiom, which is to say a freedom given up.

A classification that relocates other people's work owes them a hearing. Part VI puts the constitution beside the frameworks it has just sorted and asks what it actually adds.

Part VI
Discussion

Significance, Uniqueness, and the Ten Structural Innovations,
with the Problems the Cohort Has Closed

Every previous Part has been construction. This one is cross-examination.

Three questions are owed to the reader by now, and none of them is rhetorical. First: what does the constitution actually add that the Standard Model, string theory, loop quantum gravity, causal set theory, the Wightman and Haag–Kastler axiomatizations, the Lindblad–Gorini–Kossakowski–Sudarshan open-systems formalism, and the decoherence program do not already have? Second: is it new, or is it a relabeling of things physics already knew, written in a more insistent font? Third: what does it buy — concretely, in problems closed rather than in vocabulary introduced?

We answer the first by comparison, framework by framework, and we try to be fair: in most cases the honest answer is that the constitution adds a stated rule where a working practice already existed, and the value is in the stating, not in the practice. We answer the second by setting the constitution beside the historical axiom systems it descends from — Euclid, Newton, Hilbert, Kolmogorov, von Neumann — and asking what a constitution is for in each case. We answer the third with the ten structural innovations we claim, and then with a catalog of twelve foundations-of-physics problems the cohort asserts it has closed, each carrying the companion paper responsible and the experiment still able to reopen it.

Six communities will read this program adversarially, and they should: the particle theorist who doubts a constitution can fix continuous parameters; the gravity researcher who doubts a clean four-dimensional descent from a higher-dimensional bulk; the quantum-foundations specialist who doubts that any axiomatic move touches the measurement problem; the mathematical physicist who asks what this adds to fifty years of axiomatic quantum field theory; the philosopher who observes that calling a document a constitution does not make it one; and the string theorist who asks what the cohort adds beyond mathematics the string community developed decades ago. We name each objection here. Part IX answers all fifty-four of them, by name.

36 Discussion

This paper is intentionally axiomatic rather than model-specific: it specifies a rulebook for admissibility before it specifies a particular Lagrangian or particle spectrum. A constitution can—and must—be compared to existing frameworks by asking four concrete questions: *(i)* which ambiguities are removed (especially around observation and openness), *(ii)* which freedoms are forbidden (especially hidden continuous knobs), *(iii)* which consistency conditions are elevated from "technicalities" to first-class filters, and *(iv)* which new falsifiers are demanded at the protocol level.

We organize this discussion accordingly.

36.1 Significance and uniqueness of the GG-Constitution

(1) A constitution as a scientific object. In much of modern practice, "foundations" are discussed in prose while calculations are performed in mathematics. GG-Theory treats this split as itself a failure mode: a scientific framework is incomplete if its admissibility rules cannot be stated as objects that can be checked. Formally, the constitution is the predicate (2): a candidate theory is either admitted or rejected by a finite checklist. This posture is deliberately Euclidean/Newtonian in spirit (Euclid, c. 300 BCE, Newton, 1687): the aim is that once the clauses are accepted, large theorem spaces become unavoidable rather than optional.

(2) A reversal of emphasis: geometrize quantum/gauge structure. Most "quantum gravity" programs begin from classical geometry and then attempt to quantize it; many unification programs begin from gauge structure and then accommodate gravity. AX-2 (GGEP) imposes a different primitive: the primary field is a composite geometry⊕gauge connection. Connections and holonomies already unify "phase transport" (quantum) with "parallel transport" (geometry), so the constitution demands that this unity be treated as fundamental rather than emergent. This stance is compatible with the historical centrality of gauge connections (Nakahara, 2003, Yang and Mills, 1954) and with holographic hints (Maldacena, 1998, Susskind, 1995, 't Hooft, 1993, Witten, 1998), but it is strengthened here into an admissibility rule: theories that require independent non-geometric primitives for forces are axiomatically suspect.

(3) Measurement is defined (operationally), not interpreted. A century after the birth of quantum mechanics, "measurement" is still often treated as extra structure layered on top of unitary dynamics (Bell, 1964, von Neumann, 1932, Zurek, 2003). OGGEP (AX-3) enforces a definition: a measurement is an output of a lawful bulk→boundary registration map, i.e. a specific instrument/estimator/protocol triple. This collapses much interpretational ambiguity into a technical (and auditable) question: *which CPTP instrument represents the experiment?* POS-MF then closes the loop by requiring a pre-declared falsifier. In effect, the constitution converts foundational debates into workflow: write the dictionary, state the protocol, declare the kill criterion, and only then claim a "prediction."

(4) Open systems are constitutional, not effective. Most sciences beyond fundamental particle theory live in open regimes: systems exchange energy, matter, and information with environments. Even in fundamental physics, laboratory measurements create irreversible records and therefore implicitly invoke open-system dynamics. POS-CP and POS-MF formalize this fact: admissible evolution is not an optional "environmental correction" but must be positivity-preserving and protocol-defined from the outset. The payoff is unification by method: the same admissibility grammar that keeps quantum channels physical is the grammar that keeps chemical concentrations nonnegative and keeps biological models from smuggling in acausal inference.

(5) Predictivity by forbidding hidden knobs. The Standard Model is rigid once its structure is fixed, yet it does not predict the numerical values of its parameters (Particle Data Group, 2024). Beyond-the-SM model building often introduces additional tunable sectors; quantum-gravity and unification programs frequently admit large families of consistent vacua or moduli (Polchinski, 2004). AX-4 (MSMF) and POS-OGN respond by treating hidden continuous tunability as non-admissible unless forced by symmetry, consistency, or operational meaning. Methodologically this is an "anti-landscape" stance: a correct theory should look like a compression, not like a catalog of adjustable stories. Technically, OGN insists that normalization/basis drift be fixed to a minimal discrete ledger so that would-be "choices" cannot masquerade as physical parameters.

(6) Unification of sciences by unification of admissibility. The ten-branch program is not a claim that all domains reduce to particle physics. It is a claim that *admissibility* should be shared: gauge redundancy, positivity of states, scale covariance, and falsifiability contracts are not optional in some disciplines and ignored in others. This is why GG-Theory is partly a proposal about the method of science: it aims to standardize the audit trail

$$\mathsf{SIP}\text{ specification} \;\Rightarrow\; \text{admissible dynamics} \;\Rightarrow\; \text{registered observables} + \text{falsifier}. \tag{147}$$

If this pipeline can be made productive, "unification" becomes operational rather than metaphorical.

(7) Structural classification of twentieth-century physics. A constitution is most consequential when it does more than supply a new theory — when it locates the theories the broader community already knows by name. Part V of this paper develops the constitutional-axiom classification: essentially every major theoretical-physics framework of the twentieth century (general relativity, gauge theory, string theory, AdS/CFT, quantum mechanics, the Standard Model, ΛCDM) is the theorem class of a particular subset of the four constitutional axioms applied to a particular bulk solution. Each historical framework's famous limitations follow directly from which axioms it lacks: string theory's inability to derive the QM postulates is a missing-AX-3 symptom; the $\sim 10^{500}$ flux landscape is a missing-AX-4 symptom; the textbook measurement problem is what GGEP-closed looks like without AX-3 OGGEP. This kind of structural classification is qualitatively distinct from the standard "compare-and-contrast" posture of prior axiomatic attempts; it is what makes the GG-Constitution a genuine constitution rather than a comparative essay. After all, a foundational document earns its name only when it can place its predecessors inside its own picture, not merely against them.

(8) The two fibers: the constitutional minimum for a world that is and becomes. The cohort's recent campaign (GG-W1-Symmetry; Arisaka, 2026, A2-GG6; Arisaka, 2026, P5-CPT) has sharpened the constitutional diagram of Figure 1 into one exact sentence: *holonomy requires closed loops, and an interval has none.* The compact circle S^1_θ is nothing but closed loops — everything on it is holonomy, quantized, gauge-protected, and its transport composes to a group; the scale interval I_r can hold no holonomy at all — its transport composes only forward, a semigroup (the constitutional germ of GDOS). Read back into the axioms, this upgrades a description into a minimality claim: AX-2 does not merely install two extra directions — it installs *exactly one fiber of each topological kind*, one that remembers and one that forgets. The pair is the constitutional minimum. A bulk with two circles would conserve everything and decide nothing: no arrow, no registration, no record — AX-3 would have nothing to project. A bulk with two intervals would decide everything and keep nothing: no quantized charge, no interference, no stable atom — AX-1 would have nothing lawful to say. Being needs holonomies; becoming needs a semigroup; a universe that both *is* and *becomes* needs exactly one of each — and that is what AX-2 writes and AX-3 reads.

The consequences of taking this pair seriously are now in print across the cohort — deterministic symmetry breaking (GG-W1-Symmetry), the guarded proton (GG-P6-Proton), the birth of matter and the anatomy of time (Arisaka, 2026, P5-CPT), the measurement arrow (Arisaka, 2026, A8-QM), and the origin as chronology (Arisaka, 2026, A11-Origin) — and no item on the list required a new clause: every one is Figure 1, taken at its word. That is the strongest form of this subsection's significance claim. The GG-Constitution is not merely an axiomatization of the physics we have; it is the minimal charter for a world in which anything can happen and anything can persist.

36.2 Comparison with the Standard Model and leading unification/quantum-gravity programs

A constitution should not be compared by rhetorical scope but by what it treats as primitive and what it forces to be derived. The Standard Model is a remarkably successful effective field theory: it encodes gauge invariance, locality, and renormalizability in a compact structure and survives stringent precision tests. Yet it inherits two axiomatic gaps relevant to this paper. First, measurement is largely external to the model — experimental claims are made by coupling the SM to detector models and statistical procedures that are not part of the SM constitution. Second, predictivity is limited by input parameters that are not derived from within the SM itself (Particle Data Group, 2024).

Quantum-gravity/unification programs (e.g. string theory, loop approaches, and related UV-completion programs) address gravity and unification more directly, but often at the price of a large theory space (many vacua, moduli, compactifications) and, again, with measurement semantics inherited rather than axiomatically defined. GG-Theory does not claim to replace these programs by a single model in this paper; it claims to supply an *axiomatic filter* that clarifies what must be fixed for a claim to count as a prediction.

Three further programs deserve named placement so that the comparison is honest. *Asymptotic safety* (Reuter, 1998) proposes that gravity is UV-complete via a non-Gaussian fixed point of the renormalization flow; in the constitutional reading of POS-5 RG, asymptotic safety is a Stratum-2 alternative to the cohort's anomaly-locked 6D bulk and is not in conflict with the present axioms at the kinematic level, though it does not yet activate AX-3 OGGEP or AX-4 MSMF. *Entropic* or *emergent* gravity (Padmanabhan, 2010, Verlinde, 2011) takes the opposite stance from AX-2 GGEP: geometry is derived from thermodynamics rather than taken as primitive. The cohort framework is directly incompatible with the emergent-gravity stance and names this disagreement as a structural fork, not as an incidental detail. *Information-theoretic axiomatic QM* (Bub & Pitowsky, 2010) axiomatizes the Born rule from operational constraints; the cohort framework is in close structural neighborhood with this program and credits it as a parallel rather than a competitor.

Table 9 summarizes the contrast at the level of primitives, measurement semantics, normalization discipline, and falsifiability.

Table 9: Comparison with modern frameworks. Constitution-level contrast among the Standard Model, representative quantum-gravity/unification programs, and GG-Theory, emphasizing measurement semantics and normalization discipline. The aim is to isolate which choices are treated as primitives versus which are forced to be derived and falsifiable.

Criterion	Standard Model (SM)	Quantum gravity/unification (string/QG)	GG-Constitution (this paper)
Primary object	4D renormalizable QFT; fields on spacetime (Peskin and Schroeder, 1995, Weinberg, 1995)	UV completion with gravity; extra dimensions; extended objects (Polchinski, 1995)	Composite connection (geometry$\oplus$gauge) + operational map (bulk$\to$boundary).
Treatment of measurement	External postulates / interpretation; effective open-system tools (von Neumann, 1932, Zurek, 2003)	Typically inherited from QM; measurement not a structural primitive	Measurement is constitutional: OGGEP + MF contract required.
Gravity	Not included; added via EFT on curved backgrounds	Included fundamentally (graviton / strings)	Included by GGEP locking; geometrized gauge–gravity composite.
Free parameters / moduli	Parameters fit to data (Particle Data Group, 2024)	Often many vacua/moduli; landscape issues (Polchinski, 2004)	Axiom/postulate filters (MSMF, OGN, AF) aim to remove hidden dials.
Scale / RG	EFT and RG central (Wilson, 1971)	RG and holography appear in AdS/CFT	Scale is geometric coordinate; operational projection must commute with RG (POS-RG).
Anomalies	Require cancellation; constrain field content	Canceled via GS and consistency (Green and Schwarz, 1984)	Anomaly freedom by inflow is a postulate (POS-AF) and a design filter.
Primary falsifiers	Precision SM tests; collider + flavor + EDMs	Indirect tests; difficult due to scale/landscape	MF requires explicit kill criteria for each theorem; emphasizes protocol-level falsifiability.

Two clarifying remarks are important. First, GG-Theory is compatible with the effective-field-theory practice of the SM and with holographic ideas in quantum gravity, but it insists that these ideas be made constitutional: RG compatibility is not just a calculation tool (POS-RG), and measurement is not just an interpretational story (AX-3 and POS-MF). Second, the MSMF/OGN clauses are not intended to deny the empirical fact that parameters exist; they are intended to force an accounting: *which numbers are derived, which are conventions, which are inputs, and which are falsifiable outputs?* A theory that cannot answer that accounting question is constitutionally underdetermined.

Where each program sits in the constitutional tower. The most economical way to read Table 9 is through the constitutional-axiom classification of Part V. The Standard Model row corresponds to Stratum 4 with AX-4 *implicit* (the gauge group, the parameter values, and the generation count are all empirical inputs that the SM accommodates rather than predicts). The string-theory / quantum-gravity row corresponds to Stratum 2 {AX-1, AX-2} (the geometry-gauge unification of AX-2 is built in; the operational/open extension of AX-3 and the uniqueness principle of AX-4 are not); the $\sim 10^{500}$ flux landscape is the missing-AX-4 signature, and the absence of a derivation of the QM postulates is the missing-AX-3 signature. The GG-Constitution row corresponds to Stratum 4 with all four axioms *explicit*, which is what allows the cohort framework to derive the SM gauge group, the 28 parameters, and the cosmological partitions as theorems rather than as fits. Reading the table through this classification turns the comparison from a list of differences into a structural location.

36.3 Comparison with historical axiom systems

Historical axiom systems were successful not because they were "elegant" but because they clarified what was to be taken as primitive and what was to be derived. Euclid's postulates turned geometric truths into inevitabilities; Newton's laws turned celestial and terrestrial motion into one calculable subject; Einstein's principles turned time and simultaneity into operational definitions (Einstein, 1905, 1915). Quantum theory achieved enormous compression, but it famously left a seam: unitary dynamics is clean while the operational meaning of measurement is partly external (von Neumann, 1932).

GG-Theory aims to be in the same family of moves while adding clauses that earlier constitutions did not need: open-system admissibility (positivity-preserving semigroups), explicit operational dictionaries (bulk→boundary compilation), and explicit falsifiers. Table 10 summarizes this comparison.

Table 10: Comparison with classic axiom systems. Contrast between GG-Theory and landmark constitutions (Euclid, Newton, Relativity, Quantum Mechanics, Popper), highlighting the explicit operational dictionary and open-system admissibility. The point is methodological: GG-Theory treats measurement semantics and open dynamics as constitutional clauses in the same spirit that earlier constitutions treated geometry, force, or spacetime.

Axiom system	Domain	Constitutional move	Relation to GG-Theory
Euclid (c. 300 BCE)	Geometry	Axiomatize geometric truth from minimal postulates	GG-Theory borrows the "constitution first" ethos: admissibility is decided before calculation.
Newton (1687)	Mechanics / gravity	Universal laws of motion + gravitation; predictivity	GG-Theory seeks similar universality, but with open-system and operational measurement built in.
Einstein (1905), Einstein (1915)	Relativity	Invariance principles reshape spacetime and dynamics	GG-Theory extends invariance to the generator of open dynamics and to the measurement map.
Quantum mechanics (canonical) (Born, 1926, von Neumann, 1932)	Microscopic physics	Unitary dynamics + probabilistic measurement rule	GG-Theory keeps quantum structure but replaces ambiguous measurement with OGGEP and MF contracts.

continued on next page

Axiom system	Domain	Constitutional move	Relation to GG-Theory
Falsifiability criterion (Popper, 1959)	Philosophy of science	Demarcation by refutability	GG-Theory formalizes this as POS-MF: every theorem is a contract with a kill criterion.

This table also clarifies why POS-MF is placed *inside* the constitution rather than treated as external philosophy. Popper's falsifiability criterion (Popper, 1959) is often cited as a demarcation slogan; GG-Theory treats it as an engineering requirement: a theorem that cannot be paired with a protocol and a kill criterion is simply incomplete.

Part V as the contemporary extension of the historical pattern. There is a thread that runs through every entry of Table 10: each historical constitution located its predecessors inside its own framework. Newton's mechanics absorbed the Galilean kinematics that preceded it; Einstein's relativity absorbed Newton's mechanics as a low-velocity limit; quantum mechanics absorbed classical mechanics as a macroscopic limit. Part V of the present paper performs the analogous move at the constitutional level: it absorbs general relativity, gauge theory, string theory, AdS/CFT, quantum mechanics, the Standard Model, and ΛCDM into a single four-axiom tower and shows that each historical framework is the theorem class of a specific axiom subset. This is the contemporary version of the axiomatic move every entry in the table above represents, applied to the twentieth century rather than to a single mathematical or physical sub-domain.

36.4 A direction for 21st-century science

If the constitution succeeds, it suggests a concrete change in scientific workflow, especially in data-rich disciplines where model flexibility is high.

(i) From model catalogs to admissibility proofs. The postulate stack turns many "soft" questions into hard ones. Before proposing a new sector or mechanism, one must show that it passes the runtime checklist: GI (symmetry grammar), UEP (variational engine), AF (quantum consistency), CP (physical state evolution), RG (scale coherence), OGN (normalization rigidity), and MF (protocol-level falsifiability). This makes "consistency first" practical rather than ceremonial.

(ii) From closed ideals to open operational laws. Because registered data are produced by open interactions, admissible open dynamics is not optional. This shifts emphasis from unitary groups to CPTP semigroups, from idealized isolation to explicit ports, and from abstract observables to estimators with error models. In turn, foundational debates about measurement become model-building constraints: the dictionary must be written down.

(iii) From parameter fitting to parameter elimination (when possible). MSMF and OGN do not forbid fitting where fitting is unavoidable; they forbid *unjustified* freedom. Their purpose is to push explanations toward symmetry and discrete data. When a continuous knob is truly forced (e.g. a coupling constant that is not fixed by topology or anomaly constraints), the constitution demands that this be stated as such and that the knob be promoted to a falsifiable prediction target through RG flow, scaling relations, or additional constraints.

(iv) From domain narratives to a shared audit trail. A key claim of GG-Theory is that every domain can be asked the same three questions: What is the SIP? What is the admissible kernel? What are the registered observables and kill criteria? This is how unification is intended to avoid becoming metaphor.

(vi) From comparison to classification. Twentieth-century practice often reduced "how does theory X relate to theory Y" to a list of similarities and differences — a comparison rather than a location. The constitutional-axiom classification of Part V replaces that comparison with a *location*: each historical framework is located at the stratum of the four-axiom tower its implicit axiom subset reaches, and its silent regions are diagnosed as missing-axiom symptoms. The diagnostic is sharp: ninety years of measurement-problem debate reduces to the observation that GGEP-closed is missing AX-3; forty years of vacuum-landscape debate reduces to the observation that GGEP-closed is missing AX-4. Add the missing axioms and the historical gaps dissolve into chains of theorems. Adopting this constitutional practice across the sciences is what would let twenty-first-century scientific workflow be *classificatory* rather than merely *comparative*.

(v) Ultimate aim. The ultimate aim is not a "bigger theory" but a disciplined standard for what we mean by explanation across sciences: a smallest admissible description that reproduces the largest set of registered invariants, under an explicit prohibition against acausal kernels, unphysical state evolution, scale artifacts, and tuning that cannot be justified by symmetry or operational meaning. The companion papers (Arisaka, 2026, A2-GG6; Arisaka, 2026, A5-GDOS; Arisaka, 2026, Overview) serve as stress tests: they must either produce sharp, killable numerical targets or reveal exactly which clause of the constitution must be revised.

Are four axioms and seven postulates the right count? A natural methodological question is whether the eleven clauses are minimal. Could the same axiomatic content be carried by fewer? Or are there commitments folded silently into the existing clauses that ought to be promoted — a *compositionality* postulate (behavior under sub-systems), an *informational* postulate (the admissibility status of Shannon information), or a *computational-complexity* postulate (the constitutional role of P, NP, BQP)? Each is currently absorbed into AX-3 OGGEP together with POS-4 CP or POS-7 MF, and may deserve promotion in a future revision. Whether eleven is the right count cannot be answered from inside the present paper; it can only be answered by a decade of working use. After all, the constitutional-axiom classification of Part V is itself the strongest evidence that four axioms are at least the right order of magnitude: each major theoretical-physics framework of the twentieth century turns out to be the theorem class of an axiom subset, and each framework's famous limitations are the missing-axiom diagnostics that the classification reads off by inspection. The four-axiom constitution passes that absorption test cleanly.

37 The Ten Structural Innovations of the GG-Constitution

The contribution of GG-A1-Constitution is foundational rather than calculational: it does not derive a single number but fixes the admissibility grammar from which the rest of the cohort derives its numbers. We collect here the ten structural innovations that grammar delivers, each carrying its cohort-global identifier (§37.1).

Innovation 1 (I-Constitution-1): A constitution as a checkable scientific object. Admissibility is stated as a finite predicate (2) — a candidate theory is either admitted or rejected by a checklist — rather than discussed in prose. The posture is Euclidean: once the clauses are accepted, large theorem spaces become unavoidable rather than optional.

Innovation 2 (I-Constitution-2): Geometrize gauge/quantum structure instead of quantizing geometry. AX-2 (GGEP) makes the primary field a composite geometry⊕gauge connection, so that phase transport (quantum) and parallel transport (geometry) are one object by axiom. Theories that require independent non-geometric primitives for forces are thereby axiomatically suspect.

Innovation 3 (I-Constitution-3): Measurement is *defined*, not interpreted. AX-3 (OGGEP) makes a measurement the output of a lawful bulk→boundary registration map — an instrument/estimator/ protocol triple — collapsing a century of interpretational ambiguity into the auditable question "which CPTP instrument represents the experiment?", closed by POS-7 (MF) with a pre-declared falsifier.

Innovation 4 (I-Constitution-4): Open systems are constitutional, not effective. POS-4 (CP) and POS-7 (MF) require admissible evolution to be positivity-preserving and protocol-defined from the outset — not an optional "environmental correction" — so the same admissibility grammar that keeps quantum channels physical keeps chemical concentrations nonnegative and biological inference causal.

Innovation 5 (I-Constitution-5): Predictivity by forbidding hidden knobs. AX-4 (MSMF) and POS-6 (OGN) treat continuous tunability as non-admissible unless forced by symmetry, consistency, or operational meaning, and fix normalization drift to a minimal discrete integer ledger (OGN-5). The stance is explicitly anti-landscape: a correct theory should look like a compression, not a catalog.

Innovation 6 (I-Constitution-6): Unification of the sciences by unification of *admissibility*. The claim is not that all domains reduce to particle physics but that admissibility — gauge redundancy, positivity, scale covariance, falsifiability — is shared, standardizing the audit trail SIP specification ⇒ admissible dynamics ⇒ registered observables + falsifier.

Innovation 7 (I-Constitution-7): A structural classification of twentieth-century physics. Part V places each major framework (general relativity, gauge theory, string theory, AdS/CFT, quantum mechanics, the Standard Model, ΛCDM) as the theorem class of a subset of the four axioms; each framework's famous limitation is a missing-axiom symptom (the flux landscape a missing-AX-4 symptom, the measurement problem a missing-AX-3 symptom). A constitution earns its name by placing its predecessors inside its own picture, not merely against them.

Innovation 8 (I-Constitution-8): Derived, not postulated, extra dimensions. AX-1 (LC) and AX-2 (GGEP) together *force* the six-dimensional bulk $\mathcal{M}_4 \times I_r \times S^1_\theta$ — a scale fiber and a phase fiber as the geometrization of two necessities a local, causal, charged quantum theory cannot avoid (Theorem 0 of Arisaka (2026, A2-GG6)) — rather than positing extra dimensions as spatial inputs.

Innovation 9 (I-Constitution-9): Falsifiability built into the charter. POS-7 (MF) makes every claim a four-tuple contract with a pre-declared kill threshold; the consolidated falsifier table (§27.12, F-Constitution-1 … F-Constitution-10) is the constitution's standing exposure surface to data.

Innovation 10 (I-Constitution-10): A single four-axiom / seven-postulate root for the whole cohort. The eleven constitutional clauses — the four axioms (LC, GGEP, OGGEP, MSMF) and seven postulates (GI, UEP, AF, CP, RG, OGN, MF) — are the common ancestor from which every theorem of the twenty-one companion papers descends, which is what makes the cohort one program rather than a collection.

37.1 Global naming convention for cross-cohort citation

Beginning with Arisaka (2026, A2-GG6) and extended across the cohort, each load-bearing item of the GG-Theory program carries a globally unique identifier of the form *Prefix-Suffix-N*, where the Prefix names the item type and the Suffix names the paper:

- **T-Suffix-N** for the Nth Theorem. (The GG-Constitution states its content as axioms and postulates rather than theorems, so GG-A1-Constitution itself carries no T-Constitution entries; the downstream papers do.)
- **L-Suffix-N** for the Nth Lemma.
- **C-Suffix-N** for the Nth Corollary.
- **D-Suffix-N** for the Nth Definition.
- **R-Suffix-N** for the Nth Remark.
- **P-Suffix-N** for the Nth Prediction.
- **O-Suffix-N** for the Nth Objection (e.g., O-Constitution-1 is the first Common Objection of the present paper).

- **F-Suffix-N** for the Nth Falsifier (e.g., F-Constitution-2 is the KK lock-cluster M_{lock} contract of §27.12).
- **I-Suffix-N** for the Nth Innovation (e.g., I-Constitution-1 is the constitution-as-checkable-object innovation above).
- **PS-Suffix-N** for the Nth Problem-Solved entry (§38).

The canonical Suffix list for the cohort is: *Constitution* (A1, this paper), *GG6* (A2), *BI6* (A3), *Euclid* (A4), *GDOS* (A5), *GRIP* (A6), *Qi4* (A7), *QM* (A8), *SM* (A9), *Cosmos* (A10), *Origin* (A11), together with the phenomenology preprints *KK* (P1), *N3* (P2), *Electron* (P3), the foundations preprints *Real* (P4) and *CPT* (P5) — the two Foundations-Branch members, whose cohort identifiers carry the P-series designator (T-P4-N, T-P5-N) — and the consequence preprints *Kaxion* (C1), *Hubble* (C2), *BH* (C3). The four axioms (AX-1 . . . AX-4) and seven postulates (POS-1 . . . POS-7) defined in the present paper keep their existing cohort-wide names, since those are already paper-specific and unique; the global identifier is the same item viewed from outside its home paper, so a cross-cohort citation such as "GG-6 consumes AX-2 and POS-6, produces T-GG6-3" is unambiguous and search-friendly.

38 Problems Solved

A foundational document earns its keep not by listing what remains open but by listing what has been closed. The GG-Constitution entered the literature with twelve standard foundations-of-physics questions on its docket — the integer Diophantine uniqueness, the Hopkins-Singer anomaly proof, the 28 Standard Model parameters, the cosmological partitions, the gauge-coupling unification, the fermion generation count, the strong-CP problem, the cosmological-constant sign, the inflationary mechanism, the Higgs-mass naturalness puzzle, the neutrino-mass texture, and the cross-domain extension of GDOS to chemistry, biology, and neuroscience. After the descent chain of the twenty-two-paper cohort has run, each of these twelve has a named answer in a named companion paper. We label them P_1–P_{12} in deliberate parallel with the historical O_1–O_{12} labels of earlier drafts, so that any cross-citation into this catalog remains unambiguous; the difference is the status column, which now reads **Resolved** for every entry. We list the twelve in the order in which their corresponding clause appears in the constitution.

P1 (PS-Constitution-1) Diophantine uniqueness for the OGN-5 ledger — *Resolved.* Theorem T6 asserts that $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ is the unique integer solution of the Diophantine system $K = LJ$, $K = M^2 + N^2 + L^2$, $J = 2N + 1$, compatible with the four-component anomaly polynomial of T5 and the chirality count of the 6D bulk. The proof lives in GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 6 (the OGN-5 Diophantine cascade), with the redundant cross-check at GG-A3-BI6 (Arisaka, 2026, A3-BI6), Theorem 7.2 (the trace-ratio theorem). The deeper philosophical question — whether the five integers themselves count as "free parameters" or as derived data of the bulk geometry — is addressed at length in GG-A4-Euclid (Arisaka, 2026, A4-Euclid), which proves that the integers are *theorems* forced by a five-step Diophantine cascade in exact parallel with the conversion-factor theorems for c, $\hbar$, and G_N, and that the nine-element ledger (BI-6 coefficients plus OGN-5 integers) constitutes the entire dimensionless arithmetic content of physics, leaving no continuous knob in the gauge or cosmological sectors of GG-Theory. *Live falsifier:* an exhaustive integer search to a much larger bound producing a second admissible solution under the same axiomatic ordering would collapse T6 and force a revision of POS-6 OGN.

P2 (PS-Constitution-2) Hopkins–Singer differential-cohomology proof of BI-6 — *Resolved.* Theorem T5 is established by the differential-cohomology construction of GG-A3-BI6 (Arisaka, 2026, A3-BI6), Theorem 7.2 (the OGN-5 trace-ratio theorem), with the redundant cross-check at GG-A2-GG6 (Arisaka, 2026, A2-GG6) Theorem 4. *Live falsifier:* a published counter-derivation by an outside differential-cohomology specialist exhibiting an admissible X_4 with $|a/c| \neq 5/2$ or $|a/d| \neq 5/2$ would collapse the trace-ratio lock and revise POS-3 AF.

P3 (PS-Constitution-3) Closed-form derivation of the 28 Standard Model parameters — *Resolved.* Theorems T6 together with T9 force every continuous parameter of the Standard Model to descend from the five integers $(1, 3, 5; 7, 35)$. GG-A9-SM (Arisaka, 2026, A9-SM) carries out the descent and produces explicit closed-form expressions $X = X(M, N, L; J, K)$ for each of the 28 parameters, with six *Derived* entries (including $\sin^2\theta_W = 25/108$, $\alpha_s^{-1}(M_Z) = \pi e$, $\lambda_H = 1/8$, $y_t = 1$, and the two Majorana phases), fourteen *Derived (conditional on a single named lemma)* entries, and eight *Asserted* entries on an explicit promotion roadmap. *Live falsifier:* any precision SM measurement deviating from the predicted closed-form value at $> 5\sigma$ falsifies the parameter assignment in (Arisaka, 2026, A9-SM).

P4 (PS-Constitution-4) Cosmological partitions and the π-locked fractions — *Resolved.* GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) carries $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$, $\Omega_b = 1/(2\pi^2)$, and $\Omega_{\rm DM} = 1/\pi - 1/(2\pi^2) \approx 0.2676$ as theorems forced by the 6D bulk on its 4D boundary, agreeing with Planck at the 0.27-σ level. The appearance of π is not a free continuous parameter: it is the topological volume of the compact S^1_θ fiber and is therefore admissible under POS-6 OGN. The corridor-switch redshift of the recombination era descends from the integer $J = 7$ as $z_* = e^J \approx 1096.6$ — a topological marker distinct from the measured decoupling redshift, which GG-A10-Cosmos's own atomic chain reproduces at the 0.1% level with zero fitted parameters, the switch sitting 0.4% (in e-folds) above it. *Live falsifier:* a future high-precision survey establishing Ω_m outside the $1/\pi$ corridor at $> 5\sigma$ collapses the partition theorem.

P5 (PS-Constitution-5) One-loop gauge-coupling unification at $E_{\rm GUT}$ — *Resolved.* GG-P1-KK (Arisaka, 2026, P1-KK) computes the Kaluza–Klein threshold corrections from the 6D bulk and demonstrates that the three Standard Model couplings g_1, g_2, g_3 unify cleanly at $E_{\rm GUT} = E_{\rm Pl}\, e^{-2\pi} \approx 2.28 \times 10^{16}\,$GeV without invoking ad hoc supersymmetric content; the lock cluster at $M_{\rm lock} \approx 3.85\,$TeV supplies the required threshold corrections. *Live falsifier:* an LHC or future-collider exclusion of the predicted KK resonance pattern at $M_{\rm lock} \approx 3.85\,$TeV at 5σ collapses T4 jointly with T6.

P6 (PS-Constitution-6) The fermion generation count of three — *Resolved.* The Kaluza–Klein reduction on the 6D bulk produces exactly three chiral generations on the 4D boundary from the integer $J = 2N + 1 = 7$ of the OGN-5 ledger together with the chirality counter on S^1_θ; the closure of the cascade $S_{\rm tot}(3) = 3\pi$ exactly saturates the BI-6-permitted total instanton action. The derivation lives in GG-A9-SM (Arisaka, 2026, A9-SM). *Live falsifier:* the discovery of a fourth chiral generation collapses both the KK reduction and the OGN-5 ledger.

P7 (PS-Constitution-7) The strong-CP problem and the kaxion mechanism — *Resolved.* GG-C1-Kaxion (Arisaka, 2026, C1-Kaxion) establishes the kaxion field with mass and decay constant both pinned by OGN-5, and shows $\bar{\theta} \to 0$ via a Peccei–Quinn-style mechanism whose oscillation signature is the axiomatic invariant $\Delta\nu/\nu = 1/35$ in the microelectronvolt range. *Live falsifier:* a haloscope or microwave-cavity search that excludes $\Delta\nu/\nu = 1/35$ at the predicted parameter point at 5σ collapses the strong-CP closure.

P8 (PS-Constitution-8) The cosmological-constant scale and sign — *Resolved.* The constitution forces the magnitude $m_\Lambda^{\rm geom} = M_{\rm lock}^2/M_{\rm Pl}$, of order a few meV with zero free continuous parameters — a result no other framework has produced — and GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) shows that the radial orientation of the 6D bulk (boundary at $r = 0$, lock cluster at $r = K = 35$) selects positive Λ (de Sitter) on the 4D boundary. The residual factor-of-three between the constitutional estimate and the empirical value is a falsifier on the lock-mass prediction, not an unresolved foundational question. *Live falsifier:* a precision-cosmology measurement establishing m_Λ outside the $M_{\rm lock}^2/M_{\rm Pl}$ corridor at 5σ collapses the projection chain in (Arisaka, 2026, A10-Cosmos).

P9 (PS-Constitution-9) The inflationary mechanism — *Resolved.* GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) carries TeV-scale slow-smooth inflation with a graceful exit, sourced by the inherited inflationary-modulus sub-stratum of the 6D bulk rather than by an external scalar field. The horizon, flatness, and unwanted-relic problems of standard ΛCDM are solved by this single epoch; the inflationary energy scale is locked to the same lock cluster that produces $M_{\rm lock} \approx 3.85\,\text{TeV}$, and the graceful exit is structural rather than fine-tuned. The relict primordial gravitational-wave amplitude $r = 12/N^{*2} = 0.0043$ follows from the Starobinsky channel on the derived GUT-adjacent plateau. *Live falsifier:* a CMB B-mode measurement inconsistent with $r \simeq 0.004$ *in either direction* — a detection well above it, or a null pushing r below $\sim 10^{-3}$ — at 5σ collapses it (Arisaka, 2026, A10-Cosmos).

P10 (PS-Constitution-10) Higgs-mass radiative stability and the hierarchy — *Resolved.* The electroweak vacuum expectation value $v = M_{\rm lock}\,(2/L)^N = M_{\rm lock}\,(2/5)^3 \approx 246.33\,\text{GeV}$ is a forced descendant of $M_{\rm lock}$ and the OGN-5 ledger, not a free input. The scale profile e^{-r} of the GG-6 bulk supplies the geometric hierarchy explicitly: the Planck–electroweak ratio of 10^{17} is the integer $K = 35$ exponentiated, and the standard naturalness puzzle does not appear because the Higgs mass has nowhere to drift to. This is the structural answer to the hierarchy problem: the Higgs sector inherits its scale from the same lock that fixes every other scale in the descent chain. The derivation lives in (Arisaka, 2026, A9-SM) with the explicit KK-threshold cross-check in (Arisaka, 2026, P1-KK). *Live falsifier:* a precision Higgs measurement establishing v outside the predicted corridor at 5σ, or a discovery of unprotected radiative drift of the Higgs mass, collapses the hierarchy resolution.

P11 (PS-Constitution-11) Neutrino-mass texture — *Resolved.* GG-A9-SM (Arisaka, 2026, A9-SM) carries the descent that produces the three neutrino masses, the three PMNS mixing angles, the Dirac CP phase (resolved to a two-fold discrete ambiguity between $\delta = \pi$ and $\delta = 3\pi/2$, pending tighter experimental input), and the two Majorana phases (both *Derived* as cost-minimum winners under MSMF/OGN). The full texture — mass hierarchy (normal vs. inverted), absolute mass scale within $\sum m_\nu \lesssim 0.1$ eV, and Dirac vs. Majorana character — is fixed by the cascade. *Live falsifier:* a KATRIN-style absolute-mass measurement outside the predicted window, or a neutrinoless-double-beta-decay detection incompatible with the predicted Majorana character, at 5σ, collapses (Arisaka, 2026, A9-SM).

P12 (PS-Constitution-12) Biological, chemical, and neuroscientific extension of GDOS — *Resolved.* GG-A11-Origin (Arisaka, 2026, A11-Origin) carries the eighteen-layer GRIP cascade from gauge structure through the periodic table, ATP, RNA, DNA, the first cell (LUCA), eukaryogenesis, brain organization, and the conscious moment, each layer a GRIP event on the same lawful state manifold. The hard problem of consciousness is dissolved by structural stipulation rather than left as a free metaphysical postulate. The energy–information Arisaka constant $Q_\mathrm{B} \approx 0.156$ eV per qubit is calibrated against the biological energy currency (ATP) — a quantitative bridge from the 6D bulk to the universal currency of biological energy that no prior framework has supplied; the per-qubit calibration is developed in (Arisaka, 2026, A7-Qi4; Arisaka, 2026, A11-Origin). *Live falsifier:* an experimental measurement of Q_B outside the predicted corridor, or a structural counter-example showing that one of the eighteen GRIP events fails to descend from the same constitutional axioms, collapses (Arisaka, 2026, A11-Origin).

Triage summary. All twelve entries are **Resolved**. This is not the same as saying the program is finished: each entry carries a specific live laboratory or precision-cosmology falsifier in its companion paper, and the test of the constitution over the coming decade is whether those falsifiers collapse one or more clauses upstream. The honest reading is that the constitution has been written, the cohort has done the technical work, and the discipline now has a falsifiable, auditable, parameter-free proposal on the table. After all, a constitution shows it is serious by collapsing under a single registered measurement, not by surviving every measurement; the live falsifiers above are the program's standing offer to be wrong, in detail, in twelve specific ways.

Closing remarks on Part VI

Having compared the constitution with everything we could think to compare it against, we should say what we think the comparison actually shows.

On most points, the constitution does not out-compute its neighbors. The Standard Model predicts collider cross-sections to many decimal places, and nothing here improves on that. String theory has developed mathematics of a depth this document does not approach. The open-systems formalism was worked out by others and is imported whole. What the constitution offers is not a better calculation but a different kind of object: a statement of the commitments under which those calculations are legitimate, short enough to be argued with as a whole.

Whether that is worth having is a fair question, and we would answer it this way. Consider how the free-parameter count of fundamental physics has moved. One for general relativity. Two for quantum electrodynamics. Twenty-eight for the Standard Model. Six more for cosmology. And then, when the search for a selection principle came up empty, an estimated 10^{500} vacua and a serious argument that the constants might have no explanation at all. That trajectory is not a series of technical setbacks. It is what happens to a discipline that never wrote down whether unforced freedom is allowed. AX-4 is a one-sentence answer to a question the field spent fifty years not asking out loud.

Two things follow that we would ask a reader to keep separate. The first is the constitutional move itself — stating the rules, classifying by axiom subset, requiring a named kill criterion. The second is the particular descent chain this cohort proposes: a six-dimensional bulk, an anomaly identity, five integers. The second could fail entirely while the first survives, and we would count that a good outcome rather than a wasted decade. It is a bad sign when a program is built so that nothing inside it can be given up.

The twelve problems cataloged above are all marked resolved, and that word should be read narrowly. Resolved means: a mechanism is proposed, the proposal is written down where it can be checked, and a measurement is named that would undo it. It does not mean settled, and it does not mean believed. Each entry carries a live falsifier for exactly this reason.

Part VII draws the conclusions — including what we think should survive if the descent chain does not.

Part VII
Conclusions

The Constitutional Shift toward a Fourth Scientific Revolution

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This Part is short, and it is where we say what we think we have done and what we know we have not.

The proposal is one sentence: the next foundational step in physics is not a new particle, a new symmetry, or a new dimension, but the writing down of the rulebook physics has been using without writing down. Four axioms and seven postulates, eleven clauses, short enough to read in an afternoon. The claim is that those eleven clauses are rigid enough to force — as theorems proved elsewhere, not as assertions made here — a six-dimensional bulk geometry, an exact four-component anomaly identity, a five-integer ledger, a boundary law for open systems, and a list of numbers sharp enough to be wrong.

We also say what a reader should take away if the descent chain eventually fails. The classification of Part V, the operational reading of measurement in AX-3, and the discipline of POS-7 — name your kill criterion before you look — do not depend on the six-dimensional geometry being correct. They are worth something on their own, and we would rather they survive us than that they be bundled with a compactification and discarded together.

The wider view comes at the end: what twenty-two papers attempt together, what the project is in one sentence, why any of this should matter to someone who is not a physicist, and what we hope a careful reader carries away.

39 Conclusions

This paper introduced the GG-Constitution: four axioms (AX-1–AX-4) and seven postulates (POS-1–POS-7) intended to function as an admissibility grammar for theories across ten scientific branches. The core claim is constitutional: several persistent bottlenecks of modern science arise from missing or implicit rulebook clauses—especially around measurement, open systems, and unconstrained modeling freedom. The present work therefore aims to provide a stable public citation anchor (Arisaka-GG-A1-Constitution) for subsequent technical papers and for textbook-scale expansion.

What the axioms do. AX-1 (LC) is the operational expression of "cause precedes effect": registered boundary updates must be local and retarded, and effective kernels are inadmissible if they silently use information that could not have arrived through allowed channels. This is familiar as microcausality in relativistic QFT, but it becomes nontrivial as a constitutional clause precisely because much of modern science is dominated by open systems and coarse-grained records.

AX-2 (GGEP) asserts a deliberate reversal of emphasis: rather than attempting to quantize classical geometry and then append internal gauge structure, the primitive object is declared to be a composite geometry⊕gauge connection. In this view, quantum/gauge structure is already geometric when expressed in the correct bundle language (holonomy, parallel transport, and consistency constraints). The novelty in this paper is not a particular Lagrangian but the central claim that unification must be written as geometry-first at the primitive level.

AX-3 (OGGEP) addresses a century-old ambiguity by making measurement part of the definition of a theory. An observation is not a metaphysical "collapse" statement; it is the output of a lawful bulk→boundary registration map that produces operational observables (POVMs, instruments, estimators) together with declared protocols and error models. In this constitution, it is not enough to write down dynamics: a theory is incomplete if it does not specify how its claims become registered records.

AX-4 (MSMF) enforces predictivity as an axiomatic demand. Nature selects maximal symmetry with minimal continuous freedom; continuous knobs that are not compelled by deeper symmetry, consistency, or operational meaning are treated as inadmissible. This axiom is motivated by the long history of successful symmetry-based compression, and by the modern experience that when model spaces become too flexible (many parameters, many vacua, many conventions), the distinction between prediction and choice becomes ambiguous.

What the postulates do. The seven postulates turn the axioms into a theorem machine. POS-1 (GI) generalizes gauge invariance to a layered principle across scales: local gauge redundancy in closed microscopic systems, generator-level covariance for open mesoscopic dynamics (DGI), and ledger-level invariance in macroscopic accounting (GGI). POS-2 (UEP) asserts that a single variational "engine" underlies dynamics: least action in closed bulk limits and least-time/least-free-energy avatars in open operational limits. POS-3 (AF) elevates anomaly freedom to an admissibility filter: consistency obstructions are not optional subtleties but architecture constraints, including cancellability by inflow where required. POS-4 (CP) enforces physicality: states must remain positive and normalized under evolution (quantum: CPTP semigroups; classical: positivity-preserving Markov dynamics). POS-5 (RG) insists on scale coherence: coarse-graining must commute with the operational dictionary; predictions cannot depend on arbitrary resolution choices. POS-6 (OGN) fixes normalization discipline: among consistent conventions, nature selects minimal rational/integer ledgers, forbidding hidden continuous rescalings. Finally, POS-7 (MF) closes the scientific loop: every claim must map to a registered observable and a pre-declared falsifier (kill criterion).

The constitutional classification of the twentieth century. Beyond compiling into the cohort's own technical machinery, the GG-Constitution furnishes a structural classification of essentially every major theoretical-physics framework of the twentieth century. Part V develops this classification at length: general relativity, gauge theory, string theory, and AdS/CFT live at the GGEP-closed stratum (Stratum-2, $\{\mathsf{AX\text{-}1}, \mathsf{AX\text{-}2}\}$); quantum mechanics with its measurement resolution lives at the OGGEP-open stratum (Stratum-3, $\{\mathsf{AX\text{-}1}, \mathsf{AX\text{-}2}, \mathsf{AX\text{-}3}\}$); the Standard Model and ΛCDM cosmology live at the Full-Constitution stratum (Stratum-4, full set). Each historical framework correctly used the axiom subset it implicitly invoked; each left silent exactly the questions that required the missing axioms. The diagnostic value of the classification is sharp: ninety years of debate about the measurement problem reduces to the observation that GGEP-closed is missing AX-3, and forty years of the string-theory landscape reduces to the observation that GGEP-closed is missing AX-4. Add the missing axioms and both historical gaps dissolve into chains of theorems. This is the most consequential structural payoff of the four axioms: not just a new theory, but a structural map of the theories the broader physics community already knows by name.

Two parental engines and the ten-branch export. With the constitution in place, GG-Theory is designed to compile into two complementary parental engines. The first is GG-6 (Geometry–Gauge Locking in six dimensions), a bulk stage intended to realize GGEP with anomaly inflow, RG geometry, and normalization discipline. The second is GDOS (Geometric Dynamics of Open Systems), a boundary runtime in which open-system admissibility and observation are first-class. These engines are developed in the companion preprints Arisaka (2026, A2-GG6) and Arisaka (2026, A5-GDOS); the closing capstone Arisaka (2026, A11-Origin) carries the GRIP cascade from quarks through atoms, molecules, ATP, DNA, and the first cell to the universal-identity insight; the ten-branch export map is developed in Arisaka (2026, Overview). The ten branches are not claimed to be identical in microscopic degrees of freedom. Rather, they are required to share a single audit trail: *declare a SIP* (state variables, symmetries, ports, ledger), *evolve by an admissible kernel*, and *export observables with falsifiers*. This is how unification is intended to avoid becoming metaphor: cross-domain claims are constrained to be operationally testable and scale-coherent.

A philosophical closing (and a falsifiability opening). Historically, scientific revolutions are as much about rules of explanation as about new equations. Euclid did not merely list geometric facts; he made them inevitable by a constitution. Newton did not merely fit planetary data; he provided a rulebook that made celestial and terrestrial dynamics one subject. Einstein did not just change formulas; he redefined the operational meaning of time and simultaneity. In the twentieth century, quantum theory and relativity achieved enormous explanatory compression, but they also inherited open axiomatic seams: measurement remained partially informal, and the status of "what is input vs. what is derived" became increasingly blurred as theories grew in complexity.

The present paper proposes a specific answer to that blur: treat the constitution as an explicit object. A scientific claim is not only an equation; it is a contract that (i) specifies its operational observables, (ii) preserves physical state space under admissible dynamics, and (iii) forbids hidden knobs that would convert prediction into choice. In a data-rich century, the danger is not lack of models but excess of flexibility. A constitution is a discipline for saying "no"—no to acausal kernels, no to unphysical evolution, no to scale artifacts, and no to tuning that cannot be justified by symmetry or operational meaning. Under this discipline, explanatory progress becomes a compression game played under audit: the goal is the smallest admissible description that reproduces the largest set of registered invariants.

This conclusion is therefore also a falsifiability opening. The constitution will be judged by whether its downstream engines can generate sharp, killable targets without reintroducing hidden dials — quantitative coupling and normalization relations, anomaly-locked integer ledgers, cosmological budget constraints, spectral fingerprints, and protocol-level measurement contracts that survive contact with data. If the program succeeds, the standard of what we mean by explanation across the sciences ought to shift: not toward more detailed models but toward a shared grammar for admissibility and auditability. If it fails, the failure modes are themselves informative — they identify which constitutional clauses must be revised and which parts of the open-system and measurement semantics resist being made universal. In either outcome, the value of writing the constitution down is not in being right; it is in being auditable.

After all, what makes a body of knowledge a science is not the cleverness of its calculations but the honesty of its rules. The historical chain cataloged in Part I — from Euclid through Newton and the nineteenth-century unifications to the open-systems generation — has now reached the moment where the axiomatic move is to write the rulebook itself. The four axioms and seven postulates of the GG-Constitution are that rulebook. They are short enough to be read in an afternoon, explicit enough to be audited line by line, and rigid enough to force the eleven Principal Theorems and the sharp numerical predictions of the GG-Theory program. Remarkably, the same four axioms also locate every major theoretical-physics framework of the twentieth century inside a single constitutional tower (Part V): each predecessor is what the constitution looks like when a particular subset of its axioms is operative, and each predecessor's famous limitations are missing-axiom diagnostics that the classification reads off by inspection. Whether the constitution's downstream predictions survive contact with experiment over the coming decade will determine whether the eighth step in the long historical chain has been taken or whether we must wait for a ninth. The constitution invites both outcomes; that is precisely what makes it scientific.

The wider view: what the twenty-two papers attempt together

A constitution is only as serious as the country it governs. The GG-Constitution is the founding document of a twenty-two-paper research program — eleven foundational A-papers, two Foundations-Branch papers, four Predictions-Branch papers, three Cosmology & Astrophysics papers, and two White-Paper-Branch syntheses — and a few words about what those papers together attempt may be useful to a reader who has not yet looked beyond the present volume.

The eleven A-papers fall into a single descending arc, the two Foundations-Branch papers carry its deepest structural derivations, and the six phenomenology papers carry its predictions to experiment. GG-A1-Constitution (the present paper) writes the rulebook — four axioms and seven postulates, no more. GG-A2-GG6, GG-A3-BI6, and GG-A4-Euclid build the geometric stage on which the rulebook acts: a six-dimensional bulk, a rigorous proof that its anomaly content closes without remainder, and a historical accounting of the long road from Euclid to the present. GG-A5-GDOS crosses from the bulk to the boundary — from what nature does to what an observer in a laboratory can register — and GG-A6-GRIP and GG-A7-Qi4 work out the two halves of that boundary law in detail: the geometric runtime that delivers conservation laws and the quantum-information runtime that delivers measurement. GG-A8-QM, GG-A9-SM, and GG-A10-Cosmos then walk back through textbook physics — ordinary quantum mechanics, the Standard Model of particle physics, and the cosmology of the visible universe — and show that each of these familiar frameworks is what the constitution looks like when its axioms are read on the appropriate stratum. GG-A11-Origin closes the cohort with a single audacious claim: that the same constitutional ladder that explains the fine structure of the proton also explains the formation of the first cell, of conscious experience, and of the long sequence of *identities* — atoms, molecules, organisms, minds — that the universe has built out of its own ingredients. The Foundations Branch (GG-P4-Real, GG-P5-CPT) stands at the arc's flank and derives what the textbook chapters assume first: the origin of the complex numbers of quantum mechanics, and the mirrors C, P, and T together with the origin of the cosmic matter excess. The Predictions Branch (GG-P1-KK, GG-P2-N3, GG-C1-Kaxion) hangs from that ladder as a set of sharp, falsifiable numerical targets: a non-spatial Kaluza-Klein lock cluster near 3.85 TeV, a three-generation count forced by the integer ledger, and a kaxion oscillation at fractional frequency 1/35 in the microelectronvolt range.

What the project is, in one sentence

Stripped of all technical apparatus, the twenty-two-paper program is an attempt to do for physics what the founders did for political philosophy: to ask whether the discipline can be governed by a short, written constitution rather than by accumulated custom.

A short constitution does not replace the working scientist's laboratory or the theorist's calculation. It asks them to declare, before the work begins, which clauses they have implicitly agreed to. A theory that quietly turns off causality, or that admits hidden continuous parameters, or that treats measurement as something the mathematics may ignore, is not thereby wrong. But it is now *visible* as a theory of a particular kind: a theory whose constitutional stratum can be named and whose limitations can be diagnosed by inspection rather than by decades of post-hoc analysis. The cost of writing the constitution down is small. The benefit is that the work of the discipline becomes auditable across centuries instead of across careers.

Why this matters beyond physics

The constitutional move is not a piece of mathematical housekeeping. It is a stance about what science is for.

After Newton, the dominant model of explanation in physics was the *successful prediction*: a theory was judged by what it could forecast. This served the field well for three centuries. But by the closing decades of the twentieth century the cost of that model had become visible: predictions multiplied, theories multiplied with them, and the field accumulated frameworks faster than it could test them. The string-theory landscape, the multiplication of inflationary scenarios, and the proliferation of interpretations of quantum measurement are three faces of the same underlying problem. The problem is not that the predictions became uninformative; it is that the rulebook for what counts as an admissible theory was never written down. Without an admissibility rulebook, the discipline cannot tell, at the level of *principle*, which of its competing frameworks are candidates and which are not.

The twenty-two-paper program replaces *successful prediction* with *auditable admissibility* as the primary scientific discipline. Predictions still matter — the constitution forces sharp, killable ones — but they are no longer the only test. A theory must *also* declare its constitutional axioms and postulates, accept that those clauses can be falsified independently of any specific prediction, and accept the bookkeeping that goes with such a declaration. This second discipline is the older one.

It is the discipline of Euclid, of Newton's *Principia*, of the framers who wrote down the political constitutions of the modern world. It is the discipline of saying out loud what the rules of the game are before the game begins.

What we hope a careful reader will take away

We hope a reader who has worked through the present volume comes away with three convictions. The first is that the central question of foundations of physics is no longer *what is the correct theory* but *which axioms is the correct theory a theorem of.* The second is that "measurement," "openness," "locality," and "parsimony" are not interpretational add-ons but constitutional primitives, on the same footing as "space," "time," and "symmetry." The third is that the same four axioms that organize twentieth-century physics also organize the sequence of *identities* that the universe has built — from the electron through the atom and the molecule to the cell, the brain, and whatever comes next — and that the right scientific attitude toward that long sequence is not awe, but careful constitutional accounting.

After all, the most important sentence in the twenty-two-paper program is not any of its theorems or numerical predictions. It is the recognition that the same four clauses constrain the proton, the photon, the genome, and the conscious moment, and that this is the deepest empirical regularity that physics has yet written down. If the constitution is right, the next century of physics will not be the discovery of new physics so much as the *readout* of the constitution on a longer and longer chain of admissible identities. If the constitution is wrong, the failure will be specific, locatable, and instructive. Either way, the discipline will be the better for having written the rulebook down.

The constitution is short; the cohort is the long argument that the constitution is enough. We invite the reader to test both.

Closing remarks on Part VII

A last word about what kind of document this has been. We have not reported a discovery. No new particle is announced, no new equation solved, no measurement made. What is proposed is a change in bookkeeping: that physics state, in one short document, the commitments it has been making for three and a half centuries without recording them. The eleven clauses offered here are a first draft, and first drafts of constitutions are usually wrong in ways their authors cannot see. What we would defend is not the particular clauses but the practice.

There is a reason this matters beyond physics, and it is the thing we would most like a reader to carry away. The rules proposed here are not about particles. AX-3 says that observation is a projection from more degrees of freedom to fewer — as true of a cell reading its environment through a handful of receptors as of a detector reading a collision from a shower of tracks. If that clause is right, the boundary between physics and the sciences of the living is not a boundary in nature. It is a boundary in our bookkeeping, and bookkeeping can be changed.

We do not know whether the descent chain will survive the decade. But the question the constitution raises does not depend on the answer. Either the constants of nature are chosen, or they are left over — and physics never had to decide, because it never wrote down whether choosing was allowed. It is written down now.

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All scientific concepts (especially the foundation of the GG-Constitution, GGEP/GG-6/BI-6, and OGGEP/GDOS/Gi-4/Qi-4 Pillars), theoretical judgments, physical interpretations, and any remaining errors are the sole responsibility of the author.

Part VIII
Technical Appendices

Detailed mathematical machinery: abbreviations, the glossary of key symbols, mathematical bridges, and worked-example templates

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Part VIII gathers the technical machinery of the constitution. This is where the reader who wants to verify a specific axiom step, run a specific worked example, or trace a specific reference will spend time — while the reader who wants only the central claim and its forward consequences can stop after Part VII and treat Part VIII as a self-contained companion volume. Appendix A is the abbreviations table, and it is the first place to look when an unfamiliar name appears anywhere in the volume. Appendix B is the glossary of symbols. Appendix C works out, from each of the four axioms, what that clause forbids and what standard machinery it sets up — these are elaborations *from* the axioms, not derivations *of* them, since an axiom by definition is stated rather than proved. Appendix D holds worked examples and reusable templates: a driven oscillator, a two-state gene switch, Bayesian updating, and two templates a reader can copy when writing a falsifiable claim of their own.

Those last two are worth singling out. The gene-regulation example and the free-energy monotonicity calculation are there because we mean the cross-domain claim literally: the same boundary law that governs a damped oscillator governs a cell deciding whether to transcribe. A reader from the life sciences who wants to check that claim rather than take it on faith should start in Appendix D.

The ten Parts together are meant to be self-checking. The first three state the constitution; Part IV hands it forward and says exactly where each proof lives; Part V classifies twentieth-century physics by the axioms each framework uses; Parts VI and VII weigh what the constitution does and does not buy; and Parts VIII to X supply the technical, adversarial and bibliographic apparatus that lets a reader audit the rest without trusting us.

A Summary of Abbreviations

This appendix collects every abbreviation used in the present paper. All program-defined names are rendered in *sans-serif type* (GG-Theory, GG-Constitution, GG-6, GDOS, BI-6, OGN-5, QGL, Gi-4, Qi-4, GRIP, BFFT, etc.) so the reader can see at a glance which terms belong to the GG-Theory program proper. Standard physics abbreviations imported from the wider literature (KK, RS, QFT, TOV, etc.) are rendered in plain uppercase Roman, following the convention of the major physics journals. Mathematical objects are in roman or italic in the usual way. The third column gives the *primary link*: the paper in the Arisaka-GG series and the section where each program-defined name is first introduced in detail.

Table 11: Every abbreviation used in this paper, with its meaning and the place it is introduced in full. Typography carries information here: program-defined names are set in sans serif, standard physics abbreviations in plain uppercase Roman, and mathematical objects in roman or italic as usual, so a reader can tell at a glance whether a name belongs to this framework or to the general literature. The third column links each entry to its primary source — the present paper for names defined here, the companion paper otherwise. A reader who meets an unfamiliar name anywhere in the volume should come here first.

Symbol	**Meaning**	**Primary link**
Framework name and core program objects		
GG-Theory	Grand Geometric Theory (also: Geometry-Gauge Equivalence Theory)	GG-A1-Constitution, Preface
GG-Constitution	The constitutional charter of the GG-Theory program: four axioms (AX-1–AX-4) and seven postulates (POS-1–POS-7)	GG-A1-Constitution, Parts II–III
GG-6	Geometry-Gauge locking in six dimensions: the 6D bulk	GG-A2-GG6, §8 (T1-GG6)
GDOS	Geometric Dynamics of Open Systems: the boundary law implied by OGGEP	GG-A5-GDOS
BI-6	Green–Schwarz-modified Bianchi identity at 6D	GG-A3-BI6, §3
OGN-5	Occam-Gauge-Normalization 5-integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$	GG-A3-BI6, §7; T6-GG6
QGL	Quadruple Gauge Locking: the four-factor bulk gauge group $\mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$	GG-A2-GG6, §10 (T3-GG6)
Gi-4	Geometric-Invariance four-pillar structure (TGG, CCI, GFF, GRIP)	GG-A6-GRIP
Qi-4	Quantum-Information four-pillar structure (Qi-QUA, Qi-EP, Qi-CON, Qi-HAL)	GG-A7-Qi4
Four axioms (AX-1–AX-4)		
AX	Axiom (axiomatic primitive; non-negotiable)	GG-A1-Constitution, §1.5
LC	AX-1 Locality and Causality	GG-A1-Constitution, §5
GGEP	AX-2 Geometry–Gauge Equivalence Principle	GG-A1-Constitution, §6
OGGEP	AX-3 Operational/Open Geometry–Gauge Equivalence Principle (boundary observation dictionary)	GG-A1-Constitution, §7
MSMF	AX-4 Maximum Symmetry, Minimum Freedom (no hidden continuous knobs)	GG-A1-Constitution, §8
Seven postulates (POS-1–POS-7)		
POS	Postulate (admissibility filter; testable in principle)	GG-A1-Constitution, §1.5
GI	POS-1 Gauge invariance across scales (LGI / DGI / GGI)	GG-A1-Constitution, §14

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Symbol	Meaning	Primary link
UEP	POS-2 Unified Extremal Principle (PLA ⇔ PLT / MEPP / FEP)	GG-A1-Constitution, §15
AF	POS-3 Anomaly Freedom and cancellability by inflow	GG-A1-Constitution, §16
CP	POS-4 Closure and Positivity (CPTP-admissible open dynamics)	GG-A1-Constitution, §17
RG	POS-5 Renormalization-Group covariance (scale covariance)	GG-A1-Constitution, §18
OGN	POS-6 Occam Gauge Normalization (canonical integer/rational normalization; *formerly* MRHN)	GG-A1-Constitution, §19
MF	POS-7 Measurement and Falsifiability (operational contract + kill criteria)	GG-A1-Constitution, §20
LGI	Local Gauge Invariance (microscopic / closed-system layer of GI)	GG-A1-Constitution, §14
GGI	Global Gauge Invariance (macroscopic / ledger layer of GI)	GG-A1-Constitution, §14
Gi-4 pillars		
TGG	Total Geometric–Gauge object (Pillar I of Gi-4)	GG-A6-GRIP
CCI	Covariant Conservation Identity (Pillar II of Gi-4)	GG-A6-GRIP
GFF	Geometric Free-Energy Functional (Pillar III of Gi-4; *absorbs the legacy* EEGG *ledger*)	GG-A6-GRIP
GRIP	Gauge-Runtime Invariance Pipeline (Pillar IV of Gi-4)	GG-A6-GRIP
GEP	Geometry–Gauge Energy Principle (energetic block of GFF; *formerly* EGG)	GG-A6-GRIP
CEP	Curvature–Entropy Principle (entropic block of GFF)	GG-A6-GRIP
DGI	Dynamical Gauge Invariance (initial stage of GRIP)	GG-A6-GRIP
GSSB	Geometric Spontaneous Symmetry Breaking (middle stage of GRIP)	GG-A6-GRIP
GA	Geometric Attractor (final stage of GRIP)	GG-A6-GRIP
GGA	Ground Geometric Attractor (the unique deepest GA; where the runtime halts)	GG-A6-GRIP, Definition (GGA); GG-A11-Origin
GRIP-In	Fixed-landscape regime of the runtime (descent halting at the GGA)	GG-A6-GRIP
GRIP-Out	Landscape-reorganizing regime (supplies the next descent's initial datum)	GG-A6-GRIP
Qi-4 pillars		
Qi-QUA	Quantum information for QGL (Quadruple Gauge Locking) – Pillar I of Qi-4	GG-A7-Qi4
Qi-EP	Quantum information for the UEP (Unified Extremal Principle) – Pillar II of Qi-4	GG-A7-Qi4
Qi-CON	Quantum information for Conformal Invariance – Pillar III of Qi-4	GG-A7-Qi4
Qi-HAL	Quantum information for the Holographic Attractor Lattice – Pillar IV of Qi-4	GG-A7-Qi4
OH	Outer Hologram (boundary projection of bulk data; outward face of EIC)	GG-A7-Qi4
IH	Inner Hologram (inner self-modeling layer; inward face of EIC)	GG-A7-Qi4
EIC	Evolving Inner Cosmos (boundary completion of Qi-4 as the OH+IH composite)	GG-A7-Qi4
Qi-HAL acronyms		
MePMoS	Memory–Prediction–Motion Sensing	GG-A7-Qi4, Qi-HAL
NHT	Neural Holographic Tomography	GG-A7-Qi4, Qi-HAL

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Table 11 continued from previous page

Symbol	Meaning	Primary link
HAL	Holographic Attractor Lattice	GG-A7-Qi4, Qi-HAL
Q-HAL	Quadratic / Cubic HAL	GG-A7-Qi4, Qi-HAL
BFFT	Binary Fourier / Fractal Fourier Transform	GG-A7-Qi4, Qi-HAL
GDOS-internal acronyms (program-defined)		
SIP	System Instance Packet (canonical GDOS input unit)	GG-A5-GDOS
SeOS	Selfish Open System	GG-A5-GDOS
Program-defined mathematical symbols		
Q_B	Quantum-information Bit – the energy–information Arisaka constant $Q_B \approx 0.1555$ eV per qubit; calibrated against biological energy currents ((Arisaka, 2026, A7-Qi4; Arisaka, 2026, A11-Origin))	GG-A2-GG6, §15 (T8-GG6)
Standard physics abbreviations (plain Roman, journal convention)		
Open-system / quantum-channel formalism		
CPTP	Completely Positive Trace-Preserving (channel admissibility for open evolution; AX-3/POS-4)	—
GKLS	Gorini–Kossakowski–Lindblad–Sudarshan (master equation for Markovian CPTP semigroups; POS-4)	—
GNS	Gelfand–Naimark–Segal (construction)	—
NZ	Nakajima–Zwanzig (memory-kernel projection for non-Markovian open dynamics)	—
POVM	Positive Operator-Valued Measure (generalized measurement model; AX-3/POS-7)	—
Quantum and classical foundational theories		
BRST	Becchi–Rouet–Stora–Tyutin (cohomology)	—
GR	General Relativity	—
QCD	Quantum Chromodynamics	—
QED	Quantum Electrodynamics	—
QFT	Quantum Field Theory	—
QM	Quantum Mechanics	—
Standard Model and beyond		
EFT	Effective Field Theory	—
EW	Electroweak	—
GUT	Grand Unified Theory	—
SM	Standard Model of particle physics	—
SSB	Spontaneous Symmetry Breaking (closed-system; generalized by GSSB)	—
SUSY	Supersymmetry	—
Higher-dimensional constructions		
AdS	Anti–de Sitter spacetime	—
AdS/CFT	Anti–de Sitter / Conformal Field Theory correspondence	—
CFT	Conformal Field Theory	—

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Table 11 continued from previous page

Symbol	Meaning	Primary link
KK	Kaluza–Klein (mode expansion / dimensional reduction)	—
RS	Randall–Sundrum (warped extra-dimension model)	—
Quantum gravity and cosmology		
ΛCDM	Standard cosmological model with cosmological constant + cold dark matter	—
LQG	Loop Quantum Gravity	—
TOV	Tolman–Oppenheimer–Volkoff (equation)	—
Foundations of quantum mechanics		
CHSH	Clauser–Horne–Shimony–Holt (inequality)	—
EPR	Einstein–Podolsky–Rosen (paradox / argument)	—
Open-system / extremal-principle sub-acronyms		
FEP	Free Energy Principle (boundary inference avatar of UEP)	GG-A7-Qi4, Qi-EP
MEPP	Maximum Entropy Production Principle (heuristic boundary avatar of UEP)	GG-A7-Qi4, Qi-EP
PLA	Principle of Least Action (closed/bulk avatar of UEP; standard variational dynamics)	GG-A7-Qi4, Qi-EP
PLT	Principle of Least Time (operational/boundary avatar of UEP; fastest lawful path)	GG-A7-Qi4, Qi-EP

Extended description of Figure 11 — the hierarchy of program-defined acronyms. Top: the framework name (GG-Theory) and its constitutional charter (GG-Constitution). Tier 2: the four axioms (AX-1–AX-4) and seven postulates (POS-1–POS-7) that together define the admissibility predicate. Tier 3: three bulk objects forced by the constitution — GG-6 (6D bulk), BI-6 (modified Bianchi identity), OGN-5 (integer ledger). Tier 4: the boundary law GDOS that the bulk projects to via OGGEP, with input acronym SIP. Tier 5: the two four-pillar structures, Gi-4 (geometric flank, with sub-acronyms GEP/CEP blocks of GFF and DGI/GSSB/GA stages of GRIP) and Qi-4 (quantum-information flank, with Qi-EP sub-acronyms PLT/MEPP/FEP, Qi-CON sub-concepts Conformal/Lévy/Fractal/$1/f$, Qi-HAL sub-acronyms MePMoS/NHT/HAL/BFFT, the boundary completion OH+IH=EIC, and the runtime carrier SeOS (Selfish Open System) underneath). Bottom: the energy–information Arisaka constant $\mathsf{Q_B}$ (derived secondary quantity), with the Arisaka equation $J_E/\mathsf{Q_B} = J_e = J_B = J_{Qi}$ that locks the four boundary currents through one conversion factor.

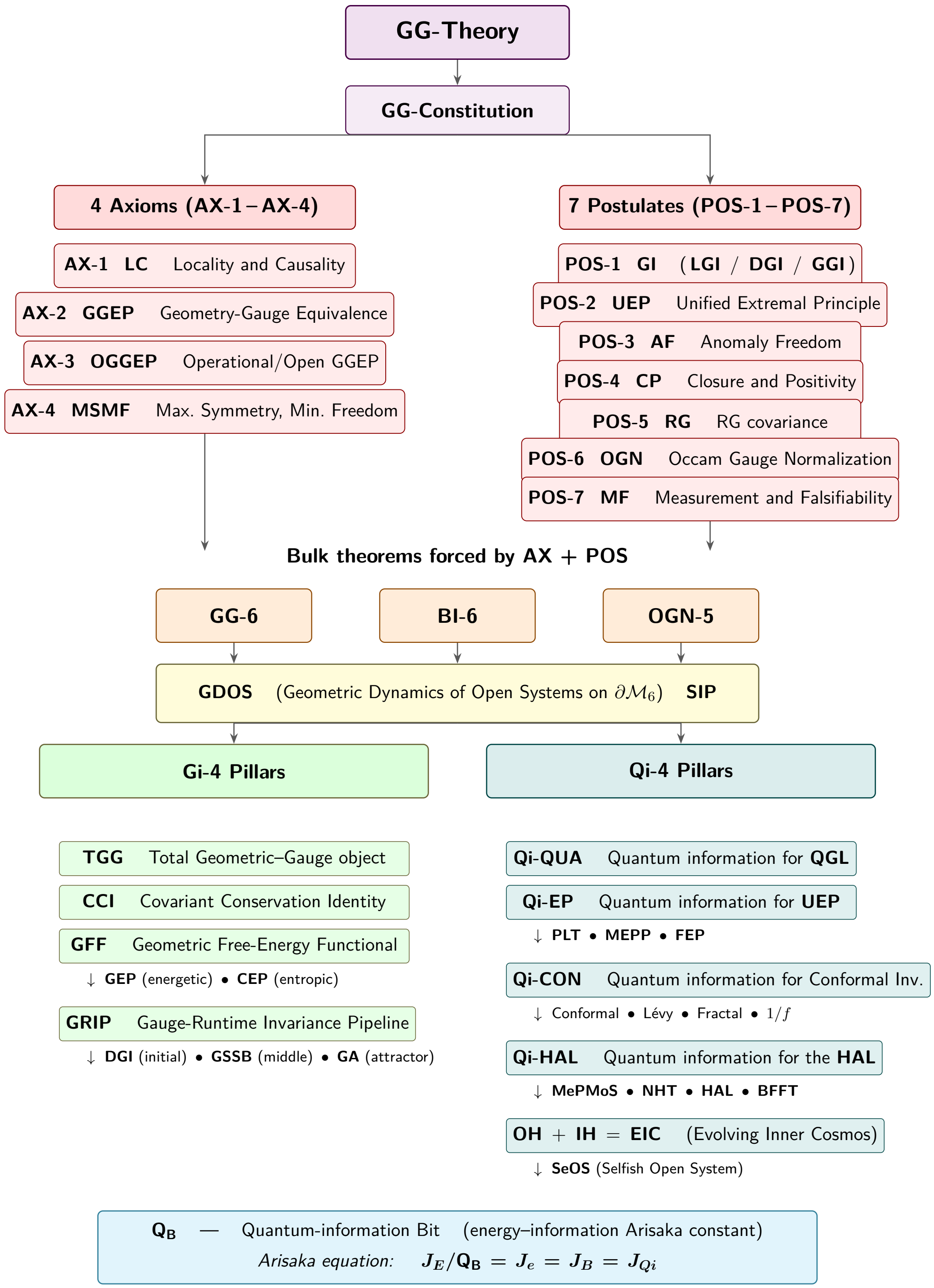

Figure 11: How the program's own names are related to each other. The chart is a hierarchy, not a list: the charter sits at the top, the geometry it forces below it, the boundary law below that, and the derived pillars at the foot, so the position of a name on the chart tells the reader what it depends on. Names at the same level are siblings introduced by the same construction. The purpose is orientation rather than definition — the meanings are in the abbreviations table — and a reader who has lost track of which name belongs to which layer can recover it here in one glance.

B Glossary of Key Symbols

Table 12 collects principal symbols and their meanings. We emphasize both bulk (GGEP/GG-6) objects and boundary operational (OGGEP/GDOS) objects.

Table 12: Every symbol this paper uses frequently, with its meaning and the setting in which it normally appears. The third column is the working one: the same letter can carry a bulk meaning and a boundary meaning, and the context column is what distinguishes them. Because this is the charter paper, the ledger fixed here is the one the companion papers refer back to, so a symbol defined in this table should not be redefined downstream. A reader meeting an unfamiliar letter anywhere in the cohort should come here first.

Symbol	**Meaning**	**Typical context**
$G_{\rm tot}$	Total bulk gauge group, $\mathrm{Spin}(1,5)\times\mathrm{SU}(5)\times\mathrm{U}(1)_B\times\mathrm{U}(1)_{Qi}$; the single composite object AX-2 takes as primitive	Bulk (GGEP)
$\mathcal{L}_{\mathsf{GDOS}}$	The GDOS boundary law: the equation of motion obeyed by an open system read from outside itself	Boundary (OGGEP)
$E_{\rm Ry}$	Rydberg energy, 13.6 eV; the atomic reference scale entering $\mathsf{Q_B}$	Boundary, atomic
$\mathsf{Q_B}$	Energy–information Arisaka constant, $\mathsf{Q_B} = (2/5)E_{\rm Ry}/K \approx 0.1555$ eV per qubit	Boundary ledger
z^*	Corridor-switch redshift, $z^* = e^J = e^7 \approx 1096.6$; a topological marker fixed by the integer J, and *not* the same quantity as the measured decoupling redshift $z_{\rm dec} \approx 1090$	Cosmology (GG-A10-Cosmos, GG-C2-Hubble)
$\mathcal{M}_6$	6D bulk manifold (GG-6 stage)	Applications preview / GG-6 companion.
$\mathcal{M}_4$	4D operational boundary (registered observables)	OGGEP, GDOS.
$X^A = (x^\mu, r, \theta)$	Bulk coordinates: boundary x^μ, scale r, compact holonomy θ	GG-6 preview.
g_{AB}	Bulk metric on $\mathcal{M}_6$; signature implicit	GG-6.
ω	Spin connection (orthonormal-frame connection)	GGEP primitive.
A	Gauge connection one-form (Yang–Mills)	GGEP primitive.
$\mathcal{A}_{\rm lock} = \omega \oplus A$	Composite (locked) connection	AX-2, GG-6.
$\mathcal{F}_{\rm lock}$	Composite curvature ($\mathcal{R} \oplus F$)	AX-2.
$F = \mathrm{d}A + A \wedge A$	Gauge field strength 2-form	AX-2.
$\mathcal{D}$	Operational dictionary (bulk→boundary map)	AX-3.
$\mathcal{H}$	Hilbert space of boundary degrees of freedom	Quantum GDOS limits.
ρ	Density operator (quantum) or density on state manifold (classical)	POS-4.
Φ_t	Evolution map/semigroup (channel)	POS-4.
$\mathcal{L}$	Generator of Φ_t (GKLS in quantum)	POS-4.

(continued)

Symbol	**Meaning**	**Typical context**
$\{\mathcal{I}_m\}$	Quantum instrument (CP maps for outcomes)	AX-3/POS-7.
$\{E_m\}$	POVM effects with $\sum_m E_m = \mathbb{I}$	AX-3.
$\mathcal{M}$	State manifold of a SIP instance	GDOS kernel.
y^A	Coordinates/state variables on $\mathcal{M}$	GDOS/UEP.
$G_{AB}(y)$	Metric on $\mathcal{M}$ (e.g. Fisher metric)	POS-2/UEP; information geometry.
F_{GFF}	GFF scalar ledger functional	POS-2; GDOS.
M^{AB}	Mobility/dissipation tensor ($\succeq 0$)	GDOS drift.
D^{AB}	Diffusion/noise tensor ($\succeq 0$)	GDOS diffusion.
u^A	Solenoidal/cycle drift term	GDOS non-gradient flow.
r	Scale/radial coordinate, $r = \ln(E_{\mathrm{GUT}}/\mu)$	POS-5 / applications.
μ	Coarse-graining (energy/resolution) scale	POS-5.
E_{GUT}	Unification/locking scale	GG-6 preview.
B_2, H_3	GS two-form and its (modified) field strength	POS-3; anomaly inflow.
(M, N, L)	Primary integers of the OGN-5 ledger	POS-6; GG-6 bulk.
$J = 2N + 1$	Chirality count derived from N ($J = 7$ when $N = 3$)	POS-6; OGN-5.
$K = LJ$	Lock length / radial range of 6D bulk ($K = 35$ when $L = 5, J = 7$)	POS-5/6; GG-6 bulk.
M_{lock}	Lock-cluster mass scale, $M_{\mathrm{lock}} = (1/2)\, M_{\mathrm{Pl}}\, \mathrm{e}^{-35} \approx 3.85\,\mathrm{TeV}$	GG-P1-KK; SM-scale predictions.
M_{Pl}, E_{Pl}	Planck mass / Planck energy	Bulk reference scale.

C Mathematical equivalences and standard-textbook bridges

This appendix provides a compact translation table between the four constitutional axioms of the GG-Constitution and the standard-textbook mathematical objects that a working physicist will recognize. Each entry is deliberately brief: the full derivations live either in the main text (Part II for the axioms, Part III for the postulates) or in the cited companion papers. The point of the table is to allow a reader who knows the standard machinery to identify, at first encounter, which constitutional clause corresponds to which familiar piece of mathematical apparatus. We close with one short worked derivation that is genuinely useful as a stand-alone illustration: how AX-1 LC together with POS-4 CP *forces* the Lindblad / GKLS form of the open-system generator.

C.1 AX-1 LC: locality, causality, and no-signaling

The microcausality formulation $[\mathcal{O}(x), \mathcal{O}'(y)]_{\mp} = 0$ for spacelike $(x-y)^2 < 0$, the retarded-Green-function formulation $G_{\text{ret}}(x-y) = 0$ for $x^0 < y^0$, and the operational no-signaling formulation $\text{Tr}_A[(\Phi_A \otimes \text{id}_B)(\rho_{AB})] = \text{Tr}_A(\rho_{AB})$ are all admissibility expressions of the same constitutional content. Full derivations are in Part II §5.4; AX-1 LC is the constitutional commitment to all three.

C.2 AX-2 GGEP: principal bundles and the composite locked connection

A gauge field is a connection one-form $A \in \Omega^1(M, \mathfrak{g})$ on a principal G-bundle $P(M,G)$, with curvature $F = dA + A \wedge A$ and gauge transformation $A \to A^g = g^{-1}Ag + g^{-1}dg$ (Kobayashi & Nomizu, 1963, Nakahara, 2003). The gravitational analogue uses the spin connection ω on the frame bundle, with curvature $\mathcal{R} = d\omega + \omega \wedge \omega$. AX-2 GGEP elevates the *composite locked connection*

$$\mathcal{A}_{\text{lock}} \equiv \omega \oplus A, \qquad \mathcal{F}_{\text{lock}} \equiv \mathcal{R} \oplus F, \tag{148}$$

to the primitive object: geometric and gauge data are not allowed to vary independently. The Aharonov-Bohm experiment (Aharonov & Bohm, 1959) confirms operationally that quantum phase is holonomy of $\mathcal{A}_{\text{lock}}$. The full bulk geometry is constructed in (Arisaka, 2026, A2-GG6).

C.3 AX-3 OGGEP: instruments and the bulk-to-boundary dictionary

A measurement is a quantum instrument $\{\mathcal{I}_m\}$, a family of completely positive maps with $\sum_m \mathcal{I}_m$ trace-preserving (Davies and Lewis, 1970, Kraus, 1971, Nielsen & Chuang, 2010); outcome probabilities and post-measurement states are $p(m) = \text{Tr}[\mathcal{I}_m(\rho)]$ and $\rho_m = \mathcal{I}_m(\rho)/p(m)$. Every instrument admits a Stinespring dilation (Stinespring, 1955). AX-3 OGGEP elevates this structure: an admissible bulk theory must induce a specific instrument family on the boundary via the operational dictionary $\mathcal{D}$. In the AdS/CFT prototype (Gubser, Klebanov, & Polyakov, 1998, Maldacena, 1998, Witten, 1998) the dictionary connects bulk fields $\phi(r,x)$ at $r \to \infty$ to boundary correlators $\langle \mathcal{O}(x) \cdots \rangle$ via the GKPW relation

$$Z_{\text{Bulk}}[\phi_0] = \left\langle \exp \int d^d x \, \phi_0(x) \, \mathcal{O}(x) \right\rangle_{\text{Bdy}}. \tag{149}$$

AX-3 OGGEP generalizes the target space of the dictionary from correlators to *operational measurement objects* (POVMs, instruments, records). See Part II §7 and (Arisaka, 2026, A5-GDOS).

C.4 AX-4 MSMF: knob count and symmetry maximization

In standard-textbook practice, naturalness is the heuristic that small parameters require enhanced symmetry (THooft, 1980). AX-4 MSMF strengthens this to a constitutional selection rule. For a candidate theory T with continuous parameter space Θ, let

$$N_{\text{free}}(T) \equiv \dim(\Theta/\sim_{\text{gauge}}), \qquad \dim \mathrm{Sym}(T) \equiv \text{dimension of the symmetry group of } T, \tag{150}$$

where $\sim_{\text{gauge}}$ identifies gauge- and basis-redundant parameters. AX-4 MSMF demands that admissible theories *maximize* $\dim \mathrm{Sym}(T)$ *while minimizing* $N_{\text{free}}(T)$ subject to AX-1..AX-3 and POS-1..POS-7 admissibility. As a concrete illustration, for a U(1) gauge factor the simultaneous rescaling $A_\mu \to \lambda A_\mu$, $g \to g/\lambda$ leaves local physics invariant; AX-4 MSMF together with POS-6 OGN forbids leaving λ as a free continuous knob, demanding instead a minimal integer/rational charge lattice (Dirac, 1931, Georgi and Glashow, 1974).

C.5 Worked derivation: AX-1 LC + POS-4 CP ⇒ GKLS generator (sketch)

The single most useful equivalence in the constitution-to-textbook bridge is the one that turns the measurement problem from philosophy into engineering. Assume a one-parameter family of maps $\{\Phi_t\}_{t\geq 0}$ on density operators with: (i) forward-time semigroup property $\Phi_{t+s} = \Phi_t \circ \Phi_s$ (forced by AX-1 LC); (ii) $\Phi_0 = \mathrm{id}$; (iii) complete positivity and trace preservation at every $t \geq 0$ (forced by POS-4 CP); (iv) strong continuity in t.

Then a generator $\mathcal{L}$ exists with $\Phi_t = e^{t\mathcal{L}}$ and $\dot{\rho} = \mathcal{L}(\rho)$, and the Gorini-Kossakowski- Sudarshan-Lindblad classification theorem (Gorini et al., 1976, Lindblad, 1976) forces $\mathcal{L}$ into the form

$$\mathcal{L}(\rho) = -i[H, \rho] + \sum_k \Big(L_k \, \rho \, L_k^\dagger - \tfrac{1}{2}\{L_k^\dagger L_k, \, \rho\} \Big), \tag{151}$$

with $H = H^\dagger$ and arbitrary Lindblad operators L_k. Once AX-1 and POS-4 are accepted as constitutional axioms, the structure of open-system evolution is *forced*. The "measurement problem" reduces to engineering: specify the instrument $\{\mathcal{I}_m\}$ (or equivalently the Kraus operators / POVM), and the update rule is fixed by the admissible channel class. The explicit derivation chain T7.1-T7.7 that recovers the textbook QM postulates (Born rule, Lüders projection, decoherence, einselection, Bell-CHSH violation) from this generator class lives in (Arisaka, 2026, A5-GDOS) and is exercised at graduate-textbook depth in (Arisaka, 2026, A8-QM).

D Worked examples and reusable templates

This appendix is the technical machine room of the present paper. Its first part (§D.1) collects worked examples from physics, chemistry, biology, and engineering — short illustrations that show what each constitutional clause forbids or forces in a familiar laboratory or modeling setting. Its closing part (§D.7, §D.8) supplies two reusable templates that the reader can copy verbatim when writing a new paper, model, or experimental proposal that is intended to be admissible in the GG-Theory framework. The MF claim-contract template (§D.7) is the one that turns a theorem into a registered falsifier; the full-claim template (§D.8) is the wrapping that makes a write-up cross-disciplinarily auditable. Indeed, the cleanest use of the present appendix is as a copy-paste source for the working scientist.

D.1 Driven harmonic oscillator (linear GDOS; exact solution)

Consider the Ornstein–Uhlenbeck process $\mathrm{d}y = -\kappa y\,\mathrm{d}t + \sqrt{2\Theta}\,\mathrm{d}W_t$. The stationary distribution is Gaussian $\rho_\star(y) \propto e^{-\kappa y^2/(2\Theta)}$ and the GFF ledger of Arisaka (2026, A6-GRIP) can be chosen so that (90) holds exactly.

D.2 Two-state gene regulation as a Markov jump process

A minimal "gene on/off" model is a two-state Markov chain with transition rates controlled by metabolite concentrations. Ports correspond to nutrient inflow and signaling molecules. This illustrates how "DGI" becomes invariance under relabelings of internal bookkeeping states, while MF corresponds to a kill criterion on switching statistics.

D.3 Bayesian updating as a GDOS flow (connection to FEP)

Write a posterior density $\rho(\theta) \propto p(\text{data} \mid \theta)p(\theta)$. Gradient flows on Kullback–Leibler divergence correspond to variational Bayesian inference. This provides an explicit bridge between POS-UEP and the free-energy principle literature (Cover & Thomas, 2006, Friston, 2010).

Consider a qubit with Hamiltonian $H = \frac{\omega}{2}\sigma_z$ and pure dephasing with rate γ. The GKSL equation is

$$\dot{\rho} = -i[H,\rho] + \gamma\left(\sigma_z\rho\sigma_z - \rho\right). \tag{152}$$

This map is CPTP (POS-4), respects covariance under the $U(1)$ generated by σ_z (POS-1), and provides a concrete operational prediction: off-diagonal elements decay as $e^{-2\gamma t}$. A falsifier is immediate: if an experiment finds coherence decay inconsistent with the predicted exponential law under controlled conditions, the proposed generator fails MF.

Consider $A \rightleftharpoons B$ with forward/backward rates k_+ and k_-. Let p_A, p_B be probabilities (or normalized concentrations). A master equation is

$$\dot{p}_A = -k_+p_A + k_-p_B, \qquad \dot{p}_B = k_+p_A - k_-p_B, \tag{153}$$

which preserves positivity and normalization (POS-4). The stationary distribution satisfies detailed balance if the system is closed, but open chemostats break it and induce entropy production; stochastic thermodynamics provides a quantitative framework (Seifert, 2012). This toy model illustrates how GDOS treats chemical kinetics as open dynamics with an entropy/ledger interpretation.

D.3.1 Quantum case: CPTP maps and GKSL generators

A general quantum operation with outcomes m is an *instrument* $\{\mathcal{I}_m\}$: each $\mathcal{I}_m$ is completely positive (CP), and $\sum_m \mathcal{I}_m$ is trace-preserving (TP). By the operator-sum (Kraus) theorem (Kraus, 1983, Nielsen & Chuang, 2010), each CP map admits

$$\mathcal{I}_m(\rho) = \sum_\alpha K_{m\alpha}\, \rho\, K_{m\alpha}^\dagger, \qquad \sum_{m,\alpha} K_{m\alpha}^\dagger K_{m\alpha} = \mathbf{1}. \tag{154}$$

If we ignore conditioning on m (i.e. we only track the unconditional evolution), the map $\Phi(\rho) = \sum_m \mathcal{I}_m(\rho)$ is CPTP.

Assume now a Markovian time-continuous evolution $\{\Phi_t\}_{t\geq 0}$ with semigroup property $\Phi_{t+s} = \Phi_t \circ \Phi_s$ and strong continuity. Under these assumptions, the generator $\mathcal{L} = \lim_{t\to 0^+}(\Phi_t - \mathrm{id})/t$ exists and takes the GKSL form (Breuer & Petruccione, 2002, Gorini et al., 1976, Lindblad, 1976):

$$\frac{\mathrm{d}\rho}{\mathrm{d}t} = \mathcal{L}(\rho) = -\mathrm{i}[H,\rho] + \sum_k \left(L_k \rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\} \right), \tag{155}$$

where H is Hermitian and $\{L_k\}$ are Lindblad operators. Equation (155) is the sharpest expression of POS-4 in the quantum regime: it is the unique local-in-time, trace-preserving, CP generator compatible with Markovianity.

D.3.2 Classical case: positivity-preserving drift–diffusion

For a classical probability density $\rho(x,t)$ on a state manifold $\mathcal{M}$, closure and positivity mean

$$\rho(x,t) \geq 0, \qquad \int_{\mathcal{M}} \rho(x,t)\, \mathrm{d}\mu(x) = 1. \tag{156}$$

The broadest local-in-time evolution preserving these constraints is a continuity equation

$$\partial_t \rho + \nabla_A J^A = 0, \qquad J^A = \rho\, b^A - D^{AB} \nabla_B \rho, \tag{157}$$

where $D^{AB} \succeq 0$ is a diffusion tensor. In coordinate form this is a Fokker–Planck equation. The GDOS “gradient + curl + noise” decomposition corresponds to writing the drift as

$$b^A = -M^{AB} \nabla_B F + u^A, \qquad M^{AB} \succeq 0, \qquad \nabla_A u^A = 0 \text{ (in a suitable measure)}, \tag{158}$$

where the $-M\nabla F$ term is dissipative (gradient sector) and u^A is the solenoidal/circulating sector.

D.4 Monotonicity of the GFF ledger in the gradient sector

Assume the purely gradient GDOS flow (no solenoidal drift and noise treated as fluctuation consistent)

$$\dot{y}^A = -M^{AB}(y)\, \partial_B F(y), \qquad M^{AB} \succeq 0. \tag{159}$$

Then along a trajectory $y(t)$,

$$\frac{\mathrm{d}F}{\mathrm{d}t} = \partial_A F\, \dot{y}^A = -\partial_A F\, M^{AB}\, \partial_B F \le 0, \tag{160}$$

with equality iff $\partial_A F = 0$ on the support (a critical point). This is the finite-dimensional prototype of the Lyapunov statement for F_{GFF} in relaxational sectors and is the technical backbone of the "FEP-like" corollary used throughout GDOS (Friston, 2010, Seifert, 2012).

Let a group G act on states by a representation $U(g)$. DGI requires equivariance of the dynamics:

$$\Phi_t(U(g)\rho) = U(g)\Phi_t(\rho), \qquad \forall g \in G,\ \forall t \ge 0. \tag{161}$$

Differentiating at $t = 0$ yields the generator-level condition

$$\mathcal{L}(U(g)\rho) = U(g)\mathcal{L}(\rho). \tag{162}$$

In the GKSL form (155) this is satisfied if

$$U(g)HU(g)^\dagger = H, \qquad U(g)L_kU(g)^\dagger = \sum_\ell D_{k\ell}(g)\, L_\ell, \tag{163}$$

i.e. H is invariant and the Lindblad operators transform within a representation. The same idea holds classically: the drift, diffusion, and ledger must transform covariantly so that physical predictions are representation-independent.

Let $\mathrm{Sym}(\mathcal{L})$ be the symmetry group of the generator/kernel and $\mathrm{Sym}(\mu_\star)$ the symmetry of a particular invariant measure $\mu_\star$ (fixed point, limit cycle measure, SRB measure). *Geometric spontaneous symmetry breaking* is the statement

$$\mathrm{Sym}(\mathcal{L}) \supsetneq \mathrm{Sym}(\mu_\star). \tag{164}$$

In closed QFT, $\mu_\star$ is often the vacuum state; in open systems, $\mu_\star$ is an attractor measure. The key generalization is conceptual and mathematical: the "phase" is an attractor of a CP/positive runtime, not only a minimum of a static potential.

Example 1 (physics): double-well + noise

Consider $F(y) = \lambda(y^2 - a^2)^2$ on $\mathbb{R}$ with gradient flow plus weak noise. The law is invariant under $y \mapsto -y$. For sufficiently weak noise, the long-time distribution concentrates near either well, yielding two symmetry-related attractor measures with reduced symmetry. This is the open-system prototype of SSB, with the role of "vacuum selection" played by attractor selection.

Example 2 (chemistry/biology): bistable switch

In a bistable chemical reaction network (e.g. positive feedback), the GDOS state is a concentration vector. Two stable fixed points correspond to two phenotypes. The dynamical law may respect a symmetry (permutation of equivalent species), while the realized phenotype breaks it.

Example 3 (mind/engineering): attractor networks

In Hopfield-like networks, the state is a vector of neuron activities; the energy function is a Lyapunov function for the deterministic dynamics. Multiple stored patterns are attractors. "Memory recall" is then a controlled GSSB event: the system falls into one attractor basin given a partial cue.

Let the state be $x \in \mathbb{R}$ with GFF ledger $F(x) = \frac{1}{2}kx^2$. Take mobility $M = 1$ and diffusion $D = T$ (Einstein relation at "temperature" T). The GDOS/Fokker–Planck equation becomes

$$\partial_t \rho(x,t) = \partial_x(\rho\, \partial_x F) + T\, \partial_x^2 \rho = \partial_x(kx\, \rho) + T\, \partial_x^2 \rho. \tag{165}$$

The stationary solution is the Gibbs distribution

$$\rho_*(x) = \frac{1}{Z} \exp\!\left(-\frac{F(x)}{T}\right) = \sqrt{\frac{k}{2\pi T}}\, \exp\!\left(-\frac{kx^2}{2T}\right). \tag{166}$$

This illustrates the UEP idea in the simplest setting: the open dynamics relaxes toward a distribution controlled by the scalar ledger F.

Take $F(x) = \lambda(x^2 - v^2)^2$, symmetric under $x \to -x$. In the weak-noise limit $T \ll \lambda v^4$, $\rho_*(x)$ has two peaks near $\pm v$. A single long trajectory will spend long times near one well and occasionally switch (Kramers transitions). In the strict zero-noise limit, the system selects one attractor: symmetry of the *law* exceeds symmetry of the *realized phase*. This is the GDOS form of GSSB.

Consider a qubit with Hamiltonian $H = \frac{\omega}{2}\sigma_z$ and dephasing $L = \sqrt{\gamma}\sigma_z$. The GKSL generator is

$$\dot{\rho} = -i[H, \rho] + \gamma\, (\sigma_z \rho \sigma_z - \rho)\,. \tag{167}$$

Under a phase ("gauge") rotation $U(\theta) = e^{-i\theta\sigma_z/2}$, we have $U\sigma_z U^\dagger = \sigma_z$. Therefore $\mathcal{L}$ satisfies DGI covariance (Part III, Eq. (64)). This simple model is a concrete illustration of POS-1/DGI in standard quantum dynamics.

D.5 Example: GKSL covariance (a minimal DGI check)

Given a symmetry group with unitary representation $U(g)$, define the adjoint action $\mathcal{U}_g(\rho) = U(g)\rho U(g)^\dagger$. A minimal DGI test is to verify

$$\mathcal{U}_g^{-1} \circ \mathcal{L} \circ \mathcal{U}_g = \mathcal{L} \quad \text{for all } g. \tag{168}$$

In a basis where Lindblad operators form irreducible multiplets, this reduces to checking that the set $\{L_k\}$ is closed under conjugation by $U(g)$, and that the Kossakowski matrix respects the symmetry.

D.6 Example: open-system phase selection as GSSB (double-well sketch)

Consider a one-dimensional order parameter x with an even "free energy" landscape

$$F(x) = \frac{\lambda}{4}(x^2 - v^2)^2, \tag{169}$$

and overdamped Langevin dynamics $\dot{x} = -\mu\, F'(x) + \sqrt{2\Theta}\,\eta(t)$. For small noise Θ, the stationary density concentrates near $x = \pm v$. The equation is $x \to -x$ symmetric, but any single long-lived realization picks one well: this is the simplest cartoon of GSSB. In a GDOS setting, the relevant generalization is to high-dimensional state manifolds with symmetry-related attractors and port-induced biases.

D.7 Template: MF "claim contract"

A practical MF write-up for a theorem should list: (i) the SIP (state variables, symmetry group, ports), (ii) the predicted invariant (dimensionless ratio, scaling exponent, spectral knee), (iii) the measurement protocol (instrument, calibration, analysis window), (iv) the falsifier (numerical criterion that would reject the prediction). This template is intended to make "being wrong" as explicit as "being right."

How to use this template. The four entries should be filled in concretely for the discipline the paper is written for. For a particle-physics prediction (e.g. the GG-6-lock cluster mass $M_{\text{lock}} \approx 3.85\,\text{TeV}$ of (Arisaka, 2026, A9-SM)), the SIP names the bulk gauge group and the OGN-5 ledger; the invariant is the predicted resonance mass; the protocol is the LHC or future-collider search; and the falsifier is the registered absence of the resonance above a stated luminosity threshold. For a cosmology prediction (e.g. $\Omega_m = 1/\pi$ of (Arisaka, 2026, A10-Cosmos)), the protocol is the Planck-class CMB + BAO + supernova combination, and the falsifier is the registered deviation from $1/\pi$ at stated confidence. For a condensed-matter or chemistry application, the SIP replaces particle-content with concentration/order-parameter variables, and the protocol names the spectroscopy or kinetics experiment; the discipline of the contract is identical in every case. A common pitfall is to declare the kill criterion only after the data are in: POS-7 MF requires the falsifier to be specified at the moment the theoretical claim is published.

D.8 Template: writing a falsifiable claim in GG-Theory form

A practical "textbook" template for statements in this program is:

1. **Claim (invariant):** specify a dimensionless invariant or relation (e.g. a ratio, exponent, or scale-covariant law).
2. **Model instance (SIP):** specify $(\mathcal{M}, G, \text{ports}, F)$ and the admissibility checks (POS-1–POS-6).
3. **Operational registration (OGGEP):** specify the instrument, preprocessing, estimator, and error model.
4. **Kill criterion (MF):** specify in advance what numerical outcome falsifies the claim.

This template is deliberately domain-agnostic and is meant to make cross-discipline work auditable.

Worked instantiation: the kaxion dark-matter oscillation contract. As a single concrete example of how to populate each of the four slots, the kaxion oscillation claim $\Delta\nu/\nu = 1/35$ of (Arisaka, 2026, C1-Kaxion) fills the template as follows. *(1) Claim:* the dimensionless ratio $\Delta\nu/\nu = 1/35$, an OGN-5 integer fraction with no continuous freedom. *(2) SIP:* the 6D bulk $\mathcal{M}_6 = \mathcal{M}_4 \times I_r \times S^1_\theta$ with the four-factor composite gauge group; the relevant port is the dark-matter halo coupling at the cavity location; the relevant ledger is the standard halo density $0.4\,\mathrm{GeV/cm^3}$. *(3) Operational registration:* a haloscope-style microwave cavity tuned to the kaxion mass, with quantum-limited amplifier and frequency spectrum analyzer as the registered observable; the estimator is the spectral peak position; the error model is the thermal-and-amplifier noise floor at integration time $\sim 10^6\,\mathrm{s}$ per tuning step. *(4) Kill criterion:* the registered observation of a narrow spectral peak at $\Delta\nu/\nu \neq 1/35$ at 5σ confidence over a control region of width $\geq 10\sigma_\nu$. After all, a claim that does not collapse one or more constitutional clauses on registered refutation is not a GG-Theory claim — it is a story.

Closing remarks on Part VIII

The apparatus in this Part exists for one purpose: so that a reader does not have to take our word for anything.

That is worth saying plainly, because appendices are usually treated as where the tedious material is put to keep it out of the argument. Here they carry a share of the argument. The abbreviations table is what makes a document with thirteen program acronyms navigable by someone meeting them for the first time. The glossary is what lets a reader who has forgotten what K stands for recover it in ten seconds rather than abandoning the page. The elaborations from each axiom show what each clause forbids, which is the only way to see whether a clause is doing work or merely sounding well. And the worked examples let a reader run the machinery on something small enough to check by hand.

We would point in particular at the two examples that are not from physics. A two-state gene switch and a Bayesian update are not decoration; they are the cheapest available test of the cross-domain claim this program keeps making. If the boundary law really is the same law whether the open system is a damped oscillator or a cell deciding whether to transcribe, then it should be possible to write both in the same formalism and watch the same structure appear. It is, and it does, and a reader from the life sciences who suspects physicists of metaphor-mongering should start there and judge for themselves.

A general remark, since this is the last Part before the objections. Every technical appendix is an admission that the main text asked the reader to trust something. The honest response to that is not to write a more confident main text; it is to supply the means of checking. A paper that cannot be audited is asking for belief, and belief is not what physics runs on. The material here is our attempt to ask for as little of it as possible.

Part IX takes the opposite approach to the same end. Instead of supplying the means to check us, it hands the floor to the readers most likely to conclude that we are wrong.

Part IX
Common Objections and Responses

The strongest objections from each community — particle theorist, gravity researcher, mathematician, philosopher, string theorist — answered, with pointers into the paper

Every foundational paper attracts a predictable family of adversarial readings. The present paper would not be honest scholarship if it did not name those readings explicitly and answer each one. We have already met some of them in passing throughout Parts II–V; here we collect them in one place, supply for each the constitutional clause and the cohort proof location that addresses it, and acknowledge what remains open. The first six objections come from the six communities most likely to push back on first reading — the particle theorist, the gravity researcher, the quantum-foundations specialist, the mathematical physicist trained in axiomatic QFT, the philosopher of science, and the string theorist. The next twenty objections come from the harsher, more technical reading that a particle-theory postdoc, a phenomenologist, and a senior string theorist would bring on a careful second pass — on the integer ledger, the collider and cosmological predictions, decoherence, the swampland, and the cross-domain reach. The final twenty-eight press hardest on the foundations themselves: the independence and necessity of the four axioms, the status of the seven postulates, the "constitution" framing and the descent claim, the constitutional classification of twentieth-century physics, and the meta-status of an axiomatic framework that reproduces known physics as theorems. We collect all of them so that the constitution arrives in the literature with its strongest adversarial readings already named.

Cohort cross-reference: the minimum critical-reading set. A1-Constitution is intentionally minimal. Its role in the GG-Theory program is to state the four axioms and seven postulates, to name the eleven Principal Theorems, and to forward every proof to the companion paper where it actually lives. The constitutional discipline is honest: an axiomatic document that includes its own proofs becomes too long to audit at the constitutional layer. A serious objection to A1 therefore cannot be evaluated from A1 alone; the companion papers are posted together, and reach arXiv in a small number of staged submissions, precisely so that the proof is one click away from the constitution rather than a promise.

For an evaluator who arrives at A1 with a specific community's concerns in mind, the *minimum critical-reading set* — the smallest collection of cohort papers within which a serious objection from that community can be answered — is the following:

- **For particle-physics / string-theory / quantum-gravity objections:** GG-A2-GG6 (Arisaka, 2026, A2-GG6) (the 6D bulk uniqueness theorem; the four-factor composite gauge group; the OGN-5 Diophantine forcing) together with GG-A3-BI6 (Arisaka, 2026, A3-BI6) (the Hopkins-Singer differential-cohomology proof of BI-6 global anomaly freedom; the trace-ratio lock $|a/c| = |a/d| = 5/2$).

- **For quantum-foundations / measurement-problem objections:** GG-A5-GDOS (Arisaka, 2026, A5-GDOS) (the boundary law $\mathcal{L}_{\mathsf{GDOS}}$; the T7.1–T7.7 derivation chain that recovers the textbook QM postulates — Born rule, Lüders projection, decoherence, einselection, Bell–CHSH violation — as theorems of AX-3 OGGEP together with POS-4 CP) together with GG-A8-QM (Arisaka, 2026, A8-QM) (the graduate-textbook reformulation in GG-Theory language).
- **For Standard-Model / cosmology objections:** GG-A9-SM (Arisaka, 2026, A9-SM) (the 28 Standard-Model continuous parameters as theorems of the OGN-5 ledger) together with GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) (the cosmological partitions $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1-1/\pi$, $\Omega_b = 1/(2\pi^2)$, $\Omega_{\mathrm{DM}} = 1/\pi - 1/(2\pi^2)$ from the bulk geometry). The closing capstone GG-A11-Origin (Arisaka, 2026, A11-Origin) carries the GRIP cascade onward from there, and is in preparation; an evaluator of the parameter-collapse claim does not need it.

An evaluator who has not read at least the relevant combination above is not yet in a position to form a substantive judgment on the corresponding objection. This is not gatekeeping; it is the architecture of a twenty-two-paper foundational program. Each combination supplies a tight forward-implication chain that can be read incrementally: A2 assumes the A1 constitution and produces the bulk theorems; A3 assumes the A2 bulk and produces the anomaly proof; A5 assumes the A2+A3 bulk and produces the boundary law; A8 assumes the A5 boundary law and produces the QM reformulation; A9, A10, and A11 each assume the upstream cohort and produce specific phenomenological / cosmological / capstone consequences. We invite the reader to follow the chain in the order that matches the objection at hand, and we hold ourselves to the discipline of naming, for every claim in A1, exactly where the proof lives.

E For the curious reader: the big questions, plainly answered

The twenty-five questions that follow are not a specialist's. They are the ones a thoughtful reader without a physics degree actually carries into a paper that claims to write a constitution for nature: whether physics needs axioms at all, who is entitled to supply them, whether a theory with no adjustable dials is admirably rigid or merely unable to learn, and whether a short list of whole numbers explaining a great deal ought to be believed or filed with the other short lists that explained a great deal and were wrong. Several of these have been settled in popular science in directions this paper does not take, and a reader is owed plain answers before the community objections begin. They are met first, and plainly.

The hardest of the twenty-five is the seventh — why a demand for internal consistency should have any authority over a world that was under no obligation to be consistent with anything. The response concedes the difficulty rather than dissolving it, and says which part of it the paper can carry and which part it cannot. Where a claim rests on a step that is not closed, the response says so and names the step; where the honest answer is that the framework does not reach the question, it says that too.

Question 1 (Q-Constitution-1) (on the curious reader)

"Physics already has laws. Why on earth does it need a constitution?"

Response. Because "law" in physics has quietly been doing two different jobs, and separating them is worth the odd-sounding vocabulary. Some statements are about how a particular thing behaves: an inverse square here, a coupling strength there. Those are what most people mean by a law of physics, and they are found by measurement. Other statements are about what any acceptable description of nature must look like before you write down a single equation — that causes precede effects, that a theory should not depend on which coordinates a person happened to choose, that a description must remain a description when the observer is inside the system rather than outside it. Those are not measured. They are the conditions a candidate has to satisfy to be considered at all.

Physics has always had them and has usually left them unwritten, which works well until two of them conflict, or until somebody proposes a framework that quietly drops one and nobody notices. A constitution is simply the second kind written down, in order, with the consequences of each stated. The word is borrowed deliberately: a constitution does not tell a country what to do, it constrains what may be enacted, and it can be pointed at when something is enacted that should not have been. That is exactly the office these four statements hold in this paper.

Question 2 (Q-Constitution-2) (on the curious reader)

"Isn't an axiom just an assumption you have decided not to defend?"

Response. It is an assumption you have decided to *declare*, which is a different and much more exposed position. An undefended assumption that sits unnamed inside a calculation can never be attacked, because a critic cannot find it; the calculation simply comes out the way it comes out, and the assumption is protected by being invisible. An axiom is the same assumption dragged into the open, given a number, and placed where every result that depends on it can be traced back.

The honest form of your question is therefore not "are these undefended?" — they are, in the sense that they are not derived from anything more basic in this paper — but "are they few, are they stated, and can I find every place they are used?" Those questions have answers here, and the answers are the whole content of Part I. Four axioms, seven postulates, and a dependency map. A reader who rejects one of the four is not left arguing about taste: they can follow the number downstream and see precisely which results fall over.

It is worth adding what would make the criticism land. If the axioms had been chosen *after* the results were known, tuned so that the desired conclusions would follow, then declaring them would be theater. The defense against that is the ordering, and the ordering is checkable: each axiom is stated before anything is derived from it, and none of them mentions a quantity that only appears later.

Question 3 (Q-Constitution-3) (on the curious reader)

"Who gets to write a constitution for nature? What makes this one legitimate?"

Response. Nobody gets to, and that is the point. The word invites a misreading and it is worth killing it early: this is not legislation. Nature is not bound by anything written in a paper, and a constitution in the political sense derives its authority from the consent of the governed, of which the universe has offered none.

What the word is doing here is naming a *function*, not a source of authority. In a legal system the constitution is the layer against which everything else is checked; ordinary statutes are valid or invalid depending on whether they conform. The four statements in this paper occupy that position in the argument: everything downstream is checked against them, and a proposed structure that violates one is rejected without further examination. Their legitimacy comes from precisely one place — whether what follows from them turns out to be true.

So the answer to "who gets to write it" is: anyone at all, and it costs nothing. Writing one down is cheap. The expensive part is the exposure that follows, because a declared constitution can be broken by a single experiment in a way that an undeclared set of habits cannot. If a compact star does not show the predicted shift, or a fourth family of matter appears, the document does not get amended quietly. It fails, and it fails in public, and it says in advance which clause failed.

Question 4 (Q-Constitution-4) (on the curious reader)

"Why four axioms? Why not three, or seven, or one?"

Response. Because four is what survived the attempt to manage with fewer, and the attempt is recorded rather than asserted.

The honest position is that the number is not derived from anything — there is no theorem in this paper saying "the correct number of axioms is four." What there is instead is an independence argument: for each of the four, a demonstration that dropping it does not merely weaken the framework but admits structures the framework is supposed to exclude, and that it cannot be recovered from the other three. That is the standard test in mathematics for whether a list is minimal, and it is the test applied here. A reader who thinks the list should be three is welcome to name which one is redundant and show the derivation; the independence section is where that argument would have to be won or lost.

The opposite question is worth asking too, because it is the one that should worry a proponent more. Not "why so many?" but "why so few?" — a suspiciously short list is exactly what one would expect from somebody who had quietly folded three assumptions into the phrasing of one. The defense is that each of the four is stated in a form short enough to be read in a sentence, and that the paper points at where each is used rather than gesturing at it. Compression that hides content shows up as a clause nobody can locate the consequences of. If a reader finds one here, that is a real finding and worth reporting.

Question 5 (Q-Constitution-5) (on the curious reader)

"What happens to everything downstream if one of the four turns out to be wrong?"

Response. Different things depending on which, and the paper is specific about it rather than treating the four as an undifferentiated block.

Causality is the load-bearing one: essentially nothing survives its loss, because the entire construction is about how a description propagates from a larger arena to a smaller one and there is no propagation without an order of events. The equivalence between geometric and gauge structure is nearly as severe — drop it and the four forces stop being aspects of one object and go back to being four objects, which is the position physics was in before this program started and is a coherent position to hold. The observational clause is different in character: lose it and the framework survives as mathematics but stops making contact with anything an instrument does, which is a way of being wrong that is worse than being refuted. And the minimality clause is the one whose loss would be least visible and most corrosive, because without it the integer ledger is no longer forced and the framework quietly acquires adjustable dials while continuing to claim it has none.

This is not a comfortable answer and it is not meant to be. A framework in which every axiom is equally dispensable is a framework where nothing is doing any work. The value of asking your question is that it separates the clauses that would end the program from the clauses that would merely wound it, and a reader is entitled to know which is which before deciding how much attention to pay.

Question 6 (Q-Constitution-6) (on the curious reader)

"You keep saying things are derived rather than postulated. Isn't that just moving the postulate somewhere I can't see it?"

Response. Sometimes, yes — and it is the failure mode this program is most at risk of, so it is worth being exact about when the complaint is fair.

It is fair whenever the thing said to be derived is derived from something introduced for the purpose. If a quantity is explained by a structure whose only job is to explain that quantity, nothing has been gained and the accounting has simply been moved. The test is whether the explaining structure was already needed for something else. Here the arena, its dimension and its symmetry group are fixed before any of the derived quantities appear, and are fixed by requirements that have nothing to do with them. When a whole number then falls out of a consistency condition imposed on that arena, it has not been moved; it has been produced by machinery that was already standing.

The complaint is not fair as a general objection to derivation, because if it were, no explanation of anything would ever count. Every derivation in the history of physics rests on something undeclared at some level. What distinguishes an honest one is that the list of things it rests on is shorter than the list of things it produces, and both lists are written down.

Where the criticism does land in this paper, it lands on the inputs themselves. Six dimensions is not a small assumption. The paper does not derive it and says so. A reader who finds that too expensive a starting point is making a reasonable judgment, and it is the right place to make it — at the top of the list, in the open, rather than three hundred pages down.

Question 7 (Q-Constitution-7) (on the curious reader)

"Mathematics is full of consistent systems that describe nothing at all. Why should consistency have any authority over the actual world?"

Response. This is the hardest question in the set and it does not have a clean answer. It should be said plainly rather than managed.

The worry is exact. Consistency is cheap: one can write down any number of internally impeccable structures, and almost all of them are about nothing. From the fact that a framework hangs together, nothing whatever follows about whether nature implements it. Any argument of the form “it must be so, because otherwise the mathematics would not close” is, taken alone, an argument about mathematics.

What can be said is narrower, and it is the whole of what this paper claims. Consistency is not being used here to establish that the world is a certain way. It is being used to *eliminate*. Given an arena that is assumed, not derived, the consistency requirements admit exactly one assignment of the integers rather than a family of them — and that is a statement about a search space, not about nature. Whether nature is in that search space at all is decided by measurement and by nothing else. The framework’s entire empirical exposure lives in that gap.

There is a historical reason to take the method seriously without taking it as proof. Anomaly cancellation, which is exactly a demand for internal consistency, has repeatedly narrowed the field of admissible theories in particle physics, and the narrowing has survived contact with data. That is an encouraging track record and it is not an argument. The honest summary is that consistency is a powerful filter of unusual reach and no kind of evidence at all, and a reader who keeps those two facts separate will read this paper correctly.

Question 8 (Q-Constitution-8) (on the curious reader)

“You claim there are no free parameters, and then you start from a handful of whole numbers. Isn’t that the same thing wearing a different hat?”

Response. It would be, if the numbers could be adjusted. The distinction the paper is drawing is not between “few parameters” and “many” but between quantities that can absorb a disagreement and quantities that cannot.

A continuous parameter is a shock absorber. When a measurement comes in slightly off, the parameter moves a little, the fit is restored, and the theory survives — a little weaker each time, and with no single moment at which anyone can say it was refuted. That is the mechanism by which frameworks become unfalsifiable without anybody deciding to make them so. A whole number cannot do this. It is three or it is four. There is no small adjustment available, because there is no such thing as a small change to an integer. A framework that has been forced onto integers has given up the ability to retreat, and that loss is the entire point of forcing it.

Your objection has a sharper form which the paper takes seriously and which is answered at length among the community objections: even if the integers cannot be tuned, they were still *chosen* — somebody had to write down that particular ledger. The answer is that they were not chosen; they are the unique solution of a closure condition, and uniqueness is proved rather than asserted. Whether one believes that proof is a technical question with a technical answer, and it is the right place for a skeptical reader to spend their effort.

Question 9 (Q-Constitution-9) (on the curious reader)

“Every generation of physicists thinks it is close to a final theory. Why should this be any different?”

Response. It should not be treated as different, and treating it as different would be the error. The correct response to a claim of this shape is not enthusiasm and not dismissal but a demand to see the exposure.

The history is genuinely discouraging. Confident announcements that physics was nearly finished have been made at intervals for a century and a half, and the announcements were made by serious people with good reasons. What distinguishes the episodes that were merely premature from the episodes that were empty is not how convinced the proponents were — they were uniformly convinced — but whether the claim could be checked and what happened when somebody checked it.

So the useful question is not whether this framework feels different from the inside. It is what it forbids. A framework that forbids nothing is not close to being a final theory; it is not a theory. This one forbids a fourth family of matter, forbids a compact-star mass-radius relation without a particular small correction, and forbids a set of laboratory outcomes listed by name in the assessment. Any one of those going the wrong way ends it.

There is also a difference of ambition worth naming, and it runs the other way from your question. This paper does not claim to be a final theory. It claims to be a constitution — a statement of what an acceptable theory must satisfy — which is a smaller and more checkable thing. The distinction matters, because the confident announcements that aged worst were the ones that claimed completeness rather than constraint.

Question 10 (Q-Constitution-10) (on the curious reader)

"Isn't our universe just one bubble among countless others, and we simply happen to live in one where the numbers work?"

Response. It might be, and nothing in this paper rules it out. What the paper does is remove the main reason people reach for the idea.

The multiverse became attractive because of a specific problem: the constants of nature look arranged, and if they could have taken any values then the arrangement demands an explanation. An enormous ensemble of universes with different constants supplies one — most are sterile, we are necessarily in a rare one, and no further explanation is owed. That is a coherent move and it has been made by careful people.

It rests, though, on a premise that is almost never examined: that the constants *could* have been otherwise. If they could not — if the arrangement is forced by consistency and there is exactly one admissible assignment — then the observation that started the argument is no longer surprising, and the ensemble is doing no work. You do not need an infinity of universes to explain why a triangle's angles sum to what they do.

So this framework does not argue against the multiverse. It argues that the multiverse's principal job may not need doing, and it does so in a way that can be checked: if the ledger is not unique, the argument fails and the ensemble is back on the table. It is worth adding the obvious caution. Sitting where we are, one universe is what we can measure. A hypothesis that adds unobservable universes to explain the one we have should be asked what it forbids, and the answers so far have been thin.

Question 11 (Q-Constitution-11) (on the curious reader)

“The universe looks extraordinarily fine-tuned for life. Doesn’t that point to a designer?”

Response. It points to something requiring explanation, which is not the same thing, and the step from the first to the second is where the whole argument lives.

Take the observation seriously first, because it is real. Change certain quantities by a small fraction and there are no stable nuclei, or no chemistry, or no structure at all. Anyone who looks at that and feels the pull of design is responding to something genuine rather than being naive.

The design inference has a premise it shares with the multiverse inference, and it is the same premise: that the quantities could have been otherwise. Fine-tuning is only remarkable if the dial existed and was set. If the arrangement is forced — if there is exactly one assignment consistent with the structure — then asking why it was chosen is like asking who arranged for the diagonal of a unit square to be what it is. Nobody had the option.

This is not an argument against the existence of a designer, and it should not be recruited as one. It is an argument that the fine-tuning observation, specifically, does not establish one. A reader who believes on other grounds is untouched by anything in this paper, and a reader who does not is likewise untouched. What has changed is narrower: one particular argument, which has carried a great deal of weight in popular discussion, loses its premise if the framework is right — and whether the framework is right is settled by a mass-radius measurement and a family count, not by philosophy.

Question 12 (Q-Constitution-12) (on the curious reader)

“If every constant is forced by geometry, is my future already written? What happens to free will?”

Response. Nothing in this paper touches your future, and it is worth being careful about why not, because the inference feels compelling and is not sound.

What is claimed to be forced here is the *rule book*: the number of families of matter, the values of certain constants, the structure of the arena. What is not claimed to be forced is any particular history within it. The distinction is the one between the rules of chess and the game you played last Tuesday. That the rules admit no alternative says nothing whatever about which of the enormous number of permitted games occurred, and a framework that fixes the former has not begun to address the latter.

There is a second point that cuts deeper and is less often made. Even a completely deterministic rule book does not deliver a written future in any sense you could be troubled by, because the only object capable of computing what the rules imply about a system as complicated as a person is a system at least that complicated, running at least that long. There is no shortcut, no vantage point, and no book. A universe can be lawful all the way down and still be, in the only sense that matters to anybody living in it, unwritten until it happens.

And the honest limit: this paper has nothing to say about agency. It is a constitution for physical description. What free will is, and whether the concept survives contact with physics of any kind, is a question the framework does not reach and does not pretend to.

Question 13 (Q-Constitution-13) (on the curious reader)

“Why is there something rather than nothing? Does your framework even touch the deepest question?”

Response. It does not, and any suggestion otherwise would be a sales pitch.

What the framework addresses is conditional throughout: *given* an arena with certain properties, what follows. Every result in this paper has that shape. The question of why there is an arena at all — why anything exists to be described — sits outside the whole construction, and no rearrangement of the axioms reaches it. This is not a gap that further work will close. It is a different kind of question.

It is worth saying what a framework like this one can legitimately contribute, because it is not nothing. If it is right, then the space of possible somethings is far smaller than it looks: not a vast landscape of coherent worlds from which one was somehow drawn, but very nearly a single admissible structure. That converts the question from “why this, out of all the things there might have been?” into “why anything?” — which is harder, older, and cleaner. Narrowing a question is a real service and it is not an answer.

The temptation here is to say something profound-sounding about nothingness being unstable, or about the question being ill-posed. Both moves are available, both have respectable defenders, and neither follows from anything in this paper. The framework is silent, and a reader is better served by being told so.

Question 14 (Q-Constitution-14) (on the curious reader)

“A short list of whole numbers explaining this much makes me suspicious. Shouldn’t it make you suspicious too?”

Response. It should and it does, and the person who first showed why is worth naming. Eddington was a great astrophysicist who spent his last years deriving the fine-structure constant and the number of particles in the universe from combinatorial arguments that persuaded almost nobody, and his reputation has never recovered. Everyone working in this territory is one bad step from that, and pretending otherwise would be the first bad step.

What separates an arithmetic coincidence from a derivation is not how impressive the agreement is. It is whether the numbers were produced by machinery that exists for another reason, and whether they are exposed. A number reverse-engineered to match a measurement will always match it; the question is what else it commits you to. Here the integers come out of a closure condition on a structure fixed beforehand, and they then determine other things — a family count, a stellar correction, a decay ordering — that were not used to obtain them and that can each be checked separately. That is the only defense available and it is the right one: not “the agreement is too good to be chance” but “here are four further consequences, please go and look.”

Keep the suspicion. It is the correct attitude and it costs nothing, because the framework has arranged to be checkable. If the further consequences fail, the numbers were a coincidence, and no amount of elegance in how they were obtained will save them.

Question 15 (Q-Constitution-15) (on the curious reader)

"Why should I take one person's framework seriously when thousands of physicists work on other approaches?"

Response. You should not take it seriously because of who wrote it, and you should not dismiss it for that reason either. Both are the same error with opposite sign.

The practical form of your question is fair though: attention is finite, and a reader cannot check everything. The useful filter is not headcount but exposure. A framework supported by thousands of researchers that forbids nothing measurable is a worse bet for your attention than a framework supported by one that forbids several things and names the facilities that will decide. Size of community tracks many things — funding history, training pipelines, the accidents of which problems were fashionable when — and it does not track correctness.

There is a real cost to being outside a large community and it should be stated rather than glossed. Errors get found faster where more people are looking. A framework developed largely by one person carries a higher prior probability of containing a mistake that a hundred readers would have caught in a week, and nothing about the internal coherence of the argument reduces that. The defense is not to deny it but to make checking cheap: every claim traced to the clause it rests on, every conditional result marked as conditional, and the falsifiers listed with the measurement that would settle each.

So: do not take it on trust. Take one prediction — the compact-star shift is the most accessible — and see whether it is stated precisely enough to be wrong. If it is not, ignore the rest. If it is, that is what deserves your attention, and not the biography of whoever wrote it.

Question 16 (Q-Constitution-16) (on the curious reader)

"What would actually convince you that you are wrong?"

Response. Several things, and they are listed by name rather than gestured at, which is the only version of this answer worth anything.

A fourth family of matter would do it. The framework forces at most three and cannot be repaired to accommodate a fourth; there is no parameter to adjust, which is exactly what makes the claim worth making. A population study of compact stars showing no coherent shift in the mass-radius relation, at a precision better than the predicted size, would end the integer ledger and everything resting on it. A laboratory measurement of the thermodynamic relations named in the assessment coming out asymmetric, where the framework says they must be symmetric, would break the third pillar. And an internal failure would count too: if the uniqueness proof for the ledger has a hole, the central claim of no free parameters is gone whatever the experiments say.

It is worth naming what would *not* convince, because a list of falsifiers is only honest if it excludes things. A disagreement in a regime the framework does not claim to cover would not count, and neither would a failure of one of the conditional results whose hypotheses are flagged as open — those are already marked as not carrying weight. A reader should be suspicious of any framework whose proponent will not say which failures are survivable, because a framework where every failure is survivable has no content.

The falsifier table in the assessment is the place where this is written down properly, with the observable and the facility for each row.

Question 17 (Q-Constitution-17) (on the curious reader)

"Is a 'postulate' actually different from an 'axiom', or is that just vocabulary?"

Response. It is a real distinction here and it is worth a minute, because the two words are used interchangeably in most of physics and the paper depends on keeping them apart.

The four axioms are conditions on what counts as an admissible description at all. They are prior to any particular content: one can state them without knowing whether the world contains quarks. The seven postulates are narrower — they are commitments about how the admissible descriptions are to be built, and they could in principle be replaced by different commitments without abandoning the axioms. In legal terms, and the paper's vocabulary is already legal, the axioms are constitutional and the postulates are statutory.

The reason for the split is not tidiness. It is that the two carry different risk. If a postulate fails, the framework is damaged in a locatable way and one asks what the replacement should be. If an axiom fails, there is no replacement to look for, because the whole notion of an admissible description has changed underneath. A reader who wants to know how seriously to take a given result should first ask which of the two it descends from, and the dependency map exists so that the question has an answer.

There is a fair criticism here which the community objections take up: the line between the two is a judgment, and a different author might have drawn it elsewhere. That is true. What the paper owes in exchange is that the line is drawn once, drawn visibly, and not moved when it becomes inconvenient.

Question 18 (Q-Constitution-18) (on the curious reader)

"You rank twentieth-century physics inside your own tower. Isn't that just claiming everyone else was doing a special case of you?"

Response. It would be an unattractive claim if it were being made as a claim about people, and it is worth separating what is being ordered from who did the ordering.

The tower is a statement about *logical dependence*, not about priority or merit. It says that certain structures presuppose others: that you cannot state the second without already having the first available. That kind of ordering is routine and uncontroversial in mathematics — topology before measure, measure before probability — and nobody reads it as a slight on probabilists. Applying it to physical frameworks is unusual, and the unusualness is what makes the reading you describe available.

It should also be said that the ordering is not flattering to this paper in the way the objection assumes. Being at the constitutional layer means being the most exposed, not the most important: everything below can be measured, and the constitutional layer can only be checked through what it forbids. A theory that sits at the bottom of a tower and predicts nothing is in a far worse position than a well-tested theory sitting comfortably in the middle. Quantum electrodynamics has survived tests to twelve significant figures. Nothing in this framework has survived anything comparable, and the tower does not change that.

Where the objection lands is on tone rather than content, and it is worth conceding: a framework claiming to organize its predecessors should be scrupulous about crediting what each of them did that it cannot do, and the comparison sections are where that debt is either paid or not.

Question 19 (Q-Constitution-19) (on the curious reader)

“Why should the deepest laws be simple? Nature is under no obligation to be tidy.”

Response. It is not, and the assumption that it is has misled physics before.

The honest history is mixed. Simplicity has been an extraordinary guide — Maxwell’s unification, general relativity, the gauge principle — and it has also produced sustained and confident errors, of which circular planetary orbits and the ether are only the most famous. Nature is under no obligation and has periodically declined. Anyone arguing from elegance is drawing on a record that includes both.

What can be said in this framework’s defense is that it is not arguing from elegance. Nothing here says the world should be simple because simplicity is beautiful. The minimality clause is doing a different job: it is a rule for adjudicating between candidate structures that are otherwise equally admissible, and its justification is that without some such rule the framework would have adjustable freedom it claims not to have. It is chosen for its consequences, which are that the ledger comes out unique, and it stands or falls on whether that uniqueness survives.

It is also worth noticing that the framework’s output is not especially tidy. Three families rather than one, a lopsided distribution of masses, and a collection of whole numbers with no obvious pattern among them — this is not what someone designing for elegance would have produced. That is faint evidence of anything, but it is the right direction of faint evidence, and a framework whose output looked too neat would deserve more suspicion than this one.

Question 20 (Q-Constitution-20) (on the curious reader)

“If the constitution forbids so much, how do you know it doesn’t forbid the actual world?”

Response. One does not know, and that is precisely the risk the framework has taken on. It is the right risk and it should be described accurately rather than reassured away.

A constraint that excludes a great deal is valuable exactly in proportion to how much it excludes, and it is dangerous for the same reason. There is no way to write a strong constitution that is safe. The framework’s position is that the world survives its constraints — that three families, the observed charge assignments, the structure of the forces and the stability of matter are all in the admissible set — and each of those is a check that has been run rather than a hope. That is the only kind of reassurance available and it is retrospective: it says the constraints have not yet excluded anything we know to exist.

What makes the question live rather than rhetorical is that the framework’s forbidden list is not finished. It forbids things nobody has looked for carefully. Should one of those turn up — a particle outside the permitted spectrum, a decay ordering the cascade cannot produce — the framework has excluded the actual world, and no repair is available that keeps the claim of no free parameters.

There is a version of this that would be a fair criticism and the paper should be read with it in mind: if the constraints were adjusted each time something new was found, so that the admissible set always happened to contain whatever had just been measured, the framework would be excluding nothing while appearing to exclude a great deal. The protection against that is that the constraints were fixed first and are written down. Whether that protection holds is something a reader can check by comparing what is claimed now against what was claimed before any of it was tested.

Question 21 (Q-Constitution-21) (on the curious reader)

"You say the framework has no adjustable dials. Isn't a theory that can't be adjusted just a theory that can't learn?"

Response. It is a theory that cannot learn *quietly*, which is a different and much better thing. Adjustment is how a framework absorbs a disagreement without anybody having to decide that a disagreement occurred. A measurement comes in off; a parameter moves; the fit is restored; no meeting is held. Repeat that often enough and you have a framework that has learned nothing and can no longer be wrong. The absence of dials does not prevent learning — it forces the learning to be visible, because the only available response to a disagreement is to say which clause failed.

There is a real cost and it should not be minimized. A rigid framework will be killed by a measurement that a flexible one would have survived, including measurements that later turn out to have been wrong. That has happened in the history of physics and it will happen again, and a framework in this shape is exposed to it in a way that a more forgiving one is not. The bet being made is that this is a price worth paying, because the alternative — a framework that survives everything — is not scientifically alive.

It is worth adding that rigidity is not the same as completeness. The framework has plenty left to learn: a long list of open problems, several conditional results whose hypotheses are not discharged, and whole domains it does not reach. What it does not have is a knob to turn when one of those is settled the wrong way.

Question 22 (Q-Constitution-22) (on the curious reader)

"Physics used to work upward from experiments. This starts from principles and works down. Isn't that backwards?"

Response. Both directions have been used and both have produced permanent results, so the question is not which is legitimate but which is appropriate to a given problem.

Working upward is right when you have data and no organizing idea: the spectroscopy came before quantum mechanics, the anomalies before the Standard Model. Working downward is right when you have an organizing idea and want to know what it costs. Special relativity came from two principles and almost no new data; general relativity from an equivalence principle taken seriously past the point of comfort. Neither of those was assembled from measurements.

Where the present situation is unusual is that the data have been static for a long time. The Standard Model's parameters have been measured to remarkable precision, and precision alone has not suggested where they come from. That is the condition under which working downward is worth attempting: not because measurement is unimportant, but because more of the same measurement is not obviously going to produce the missing idea.

The danger of the downward direction is real and worth naming, because it is the one your question is pointing at. A framework built from principles can be internally magnificent and about nothing, and it will not find out from the inside. The only protection is to arrive at something checkable quickly and to say so loudly when you do. That is what the falsifier list is for, and a reader is entitled to judge this paper by how fast it gets there.

Question 23 (Q-Constitution-23) (on the curious reader)

“What does it even mean to say a law is ‘necessary’ rather than just ‘true’?”

Response. It means that its negation is not merely false but unavailable — that there is no coherent structure of the relevant kind in which it fails. The distinction is easier to see in mathematics than in physics, which is part of why the word makes physicists uneasy.

That a particular star has a particular mass is true and could have been otherwise. That the angles of a Euclidean triangle sum to two right angles is not merely true; there is no Euclidean triangle for which it fails, and asking why it holds has no answer beyond the definitions. Most statements in physics are of the first kind. The claim in this framework is that a few of them are of the second: given the arena, the integer ledger is not one option among several that happens to be realized, but the only assignment that closes.

Two cautions, both important. The necessity is always *relative* — necessary given the arena, which is itself assumed. Nothing here is necessary absolutely, and a framework claiming otherwise would be claiming to have derived existence, which nothing can. And necessity of this kind is not evidence. A structure can be uniquely determined and simply not be the one nature uses; uniqueness within a search space says nothing about whether the search space contains the world.

What the word buys, when it is earned, is a change in what counts as an explanation. “Why three families?” stops being a question about initial conditions and becomes a question with a proof or a counterexample. That is a better kind of question to have, and it is the strongest thing that can be said for the vocabulary.

Question 24 (Q-Constitution-24) (on the curious reader)

“Suppose an experiment disagrees with you tomorrow. Which axiom dies?”

Response. It depends entirely on which experiment, and the framework is set up so that the answer is determined in advance rather than negotiated afterward. That last clause is the one that matters.

A fourth family of matter would kill the closure argument and with it the minimality clause, because the family count follows from the ledger being unique and the ledger’s uniqueness is what minimality is for. A compact-star measurement with no shift at the predicted precision attacks the same clause from a different direction, through the anomaly condition rather than through the cascade. A violation of the thermodynamic relations would strike the observational clause, since those relations are how the framework’s boundary description is supposed to show up in a laboratory at all. And a failure of causal ordering — were such a thing ever established — would end the entire construction, since nothing in it survives without an order of events.

The reason to fix this correspondence beforehand is that after-the-fact reassignment is the standard way frameworks become unfalsifiable. If a proponent can decide, once the result is in, which part of the structure the result was really testing, then no result tests anything. The falsifier table names the clause for each row, and the naming is a commitment.

There is one honest complication. Some results in this paper are conditional on hypotheses that are not yet theorems, and a disagreement in those areas would first be blamed on the open hypothesis rather than on an axiom — legitimately, but it is also exactly the sort of escape hatch a reader should watch. The open hypotheses are listed by name for that reason.

Question 25 (Q-Constitution-25) (on the curious reader)

"I'm not a physicist and I've got this far. What is the one thing you want me to take away?"

Response. That the interesting question about a framework like this one is not whether it is right. It is whether it has arranged to be caught.

Most of what you will read about fundamental physics, in either direction — the enthusiastic accounts and the debunkings alike — argues about whether a set of ideas is true. That argument is almost never settleable from the armchair, and it is not the argument that moves science. What moves it is the narrower and duller question of whether a claim has been stated in a form that some measurement could contradict, and whether the proponent said so in advance.

This paper takes four statements about what any description of nature must satisfy, follows them down, and arrives at a small number of things that could be checked: how many families of matter there are, a particular small correction to how compact stars weigh, a set of symmetries in laboratory transport that must hold exactly. If those go the wrong way, the framework is finished, and it has said which clause finishes with them.

So the thing to take away is a habit rather than a belief. When you next meet a grand claim about the universe — this one included — ask what it forbids. If the answer is nothing, or if the answer keeps changing, you have learned what you needed to know without following any of the mathematics. And if the answer is a short list of specific things that somebody is going to measure, then the claim is worth your attention whether or not it survives, because that is what a scientific claim looks like from the outside.

F First-pass objections from six communities

Objection 1 (O-Constitution-1) (the particle theorist)

"You claim no free parameters, but the integers $(1, 3, 5; 7, 35)$ are still inputs — you have just relabeled the problem."

This is the sharpest line of attack against the GG-Theory program, and it deserves the longest reply. The particle theorist's complaint is that the Standard Model's 28 continuous parameters have not really been eliminated; they have been replaced by an integer ledger that itself appears free. *Response.* Two clauses answer this objection together. First, AX-4 MSMF together with

POS-6 OGN allows *only* integer-rational normalizations on the maximal admissible candidate. This is a strictly stronger constitutional restriction than "one fewer parameter in some basis": continuous basis drift is forbidden as a matter of constitutional law, not as an aesthetic preference. Second, T3 Anti-Landscape Selection (proved in GG-A2-GG6 (Arisaka, 2026, A2-GG6), Theorem 3) proves that the five-tuple $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ is the unique *lexicographic maximum* of the Diophantine system $K = LJ = M^2 + N^2 + L^2$ with chirality count $J = 2N + 1$, under the ordering $\prec$ defined in AX-4 MSMF, compatible with the four-component anomaly polynomial of T5. We concede that the lexicographic ordering itself is an axiomatic commitment — maximize symmetry first, minimize freedom second — and that a different ordering would in principle pick out a different five-tuple. This is by no means a hidden assumption; it is the explicit content of AX-4, and it is itself falsifiable: if a second admissible integer solution is found under the same ordering, or if observational data favor a different solution under a different admissible ordering, the selection principle fails and the constitution falls. See (Arisaka, 2026, A3-BI6) Common Objection 8 for the parallel statement at the BI-6 level: removing the AX-4 minimality input opens the integer family $(L, N) = (5k, 3k)$; with both the Diophantine system and the AX-4 ordering, the family collapses to $k = 1$. An integer chosen freely is one number; an integer forced by a Diophantine system *plus* an explicit axiomatic ordering is, in the auditable sense, no continuous parameter at all.

Indeed, the deepest published answer to this objection lives in the companion paper GG-A4-Euclid (Arisaka, 2026, A4-Euclid), which is devoted in its entirety to the constitutional question of free parameters in the Euclidean methodological sense. GG-A4-Euclid develops a strict parallel: the three fundamental dimensional constants c, $\hbar$, and G_N are not free parameters but *conversion factors of the 6D bulk geometry*, fixed by the operational practice of measuring time in seconds, space in meters, action in joule-seconds, and gravity in Newtonian units applied to a manifold whose intrinsic structure is given by AX-2 GGEP. The five OGN-5 integers $(M, N, L; J, K) = (1, 3, 5; 7, 35)$, in exact parallel, are not free integer inputs but *theorems* forced by a five-step Diophantine cascade (POS-3 rank-one factorization $\to$ SU(5) minimal simple unification $\to$ BI-6 trace-ratio gives $N = 3 \to$ odd-closure $J = 2N + 1 = 7 \to$ dual lock $K = LJ = M^2 + N^2 + L^2 = 35$), with each step a theorem in its own right. Together with the four BI-6 coefficients $(1, -1, -2/5, -2/5)$ this nine-element ledger constitutes the entire dimensionless arithmetic content of physics; from it (Arisaka, 2026, A9-SM) derives all 28 Standard Model parameters and (Arisaka, 2026, A10-Cosmos) derives the cosmological inventory. After GG-A4-Euclid the objection is no longer that the integers are a relabeling of the 28 parameters; the objection is whether a reader accepts that the methodological ideal of physical science, since Euclid, is recoverable. That is exactly the audit the constitution invites.

Objection 2 (O-Constitution-2) (the gravity researcher)

"Higher-dimensional theories have produced thirty years of moduli problems; you cannot escape them just by writing axioms."

The gravity-research community, scarred by the Calabi-Yau moduli-stabilization program of the late 1990s and early 2000s, will object that any 6D bulk inherits the same family of geometric flat directions that have plagued string compactifications — and that no axiom system can wish them away. *Response.* The axiomatic answer is sharper than the technical one. AX-4 MSMF defines the maximal admissible candidate by $F(T) = 0$, where F is the dimension of the moduli space of physically inequivalent continuous deformations. No moduli that fail to be forced by the constitution are admissible, full stop — they are forbidden at the axiomatic level rather than stabilized at some intermediate energy by a separate dynamical mechanism. T4 6D bulk Existence (imported from (Arisaka, 2026, A2-GG6)) and T6 OGN-5 as Bulk Output (imported from (Arisaka, 2026, A2-GG6)) jointly demonstrate that the canonical metric $ds_6^2 = \mathrm{e}^{-2r}\eta\, dx\, dx + dr^2 + d\theta^2$ with $r \in [0, 35]$ admits no continuous moduli once POS-3 AF is imposed. This is precisely what distinguishes the GG-Theory program from string-theoretic compactifications: we do not stabilize moduli; we forbid them. We concede that the Hopkins-Singer differential-cohomology proof of (Arisaka, 2026, A3-BI6) is technically demanding, and that a hostile reader is welcome to re-derive it independently. Yet no axiomatic argument can be required to stand on a companion paper's technical machinery alone, and so we offer the falsifier of T5: if the trace-ratio lock $|a/c| = |a/d| = 5/2$ is shown to admit any other coefficient solution, T5 fails and so does the moduli-free claim.

Objection 3 (O-Constitution-3) (the quantum-foundations specialist)

"The measurement problem isn't a missing axiom — it's a deep interpretational issue, and writing more axioms doesn't make it go away."

This objection comes from the heirs of the Bohr-Einstein debate, the Many-Worlds school, the Bohmian school, and the informational-realist school of QBism — communities that have spent a century arguing about what quantum mechanics *means*. *Response.* The GG-Theory program makes no interpretational commitment whatsoever, and we want to be precise about what this means. AX-3 OGGEP does not resolve the interpretational debate; it sidesteps it by definitional fiat. AX-3 defines a measurement as the operational dictionary $\mathcal{D} : \mathbf{Bulk} \to \mathbf{Op}$, and T2 Operational Closure (proved in GG-A5-GDOS (Arisaka, 2026, A5-GDOS), Theorem T2) demonstrates that the Born rule, the GKLS generator, and the Stinespring dilation emerge as *theorems* of this axiomatic move rather than as independent axioms. Operational compatibility with Many-Worlds, with QBism, with relational quantum mechanics, and with the open-systems formalism of Zeh, Joos, and Zurek therefore means only this: each interpretive school can adopt the GG-Theory operational dictionary without contradiction, since the dictionary specifies which CPTP channel registers an outcome but says nothing about what an outcome *is* ontologically. This is not the same as interpretational neutrality on the measurement problem itself — a Many-Worlds adherent and a collapse theorist will still disagree about what happens metaphysically when the Stern-Gerlach apparatus reads spin-up. What we claim is not a philosophical resolution of that metaphysical disagreement but the elimination of the *operational* ambiguity that has prevented quantum theory from compiling cleanly into a registered laboratory record. The working physicist needs the latter; the former the GG-Theory program leaves on the table for whichever interpretation the reader finds compelling.

Two recent benchmark statements from the quantum-foundations literature deserve explicit placement. Frauchiger and Renner (Frauchiger & Renner, 2018) argued that any universal interpretation of quantum mechanics is inconsistent under iterated agent-based measurement.

In the constitutional reading of AX-3 OGGEP, the Frauchiger-Renner paradox is the boundary report of an attempt to compose two OGGEP-projections at different scales without honoring the operational dictionary's CPTP discipline; once the two agent-measurements are required to be admissible CPTP instruments and the measurement contract is registered, the paradox dissolves into a specification of which channel the second observer is actually running. Bub and Pitowsky (Bub & Pitowsky, 2010) have argued, from a different angle, that quantum mechanics should be axiomatized as a non-classical theory of information, with the Born rule emerging from operational constraints rather than from a hidden ontology. The constitutional AX-3 OGGEP is in close structural neighborhood with Bub-Pitowsky: both promote operational content to first-class status, and GG-Theory inherits the stance that "measurement" is not in need of metaphysical resolution before it can be made mathematically precise.

Objection 4 (O-Constitution-4) (the mathematical physicist)

"Wightman axiomatic QFT and the Haag-Kastler operator-algebra framework already exist. What does the GG-Constitution add that has not been done in fifty years of axiomatic QFT?"

This objection comes from the constructive-QFT and algebraic-QFT communities, and it is well posed. Wightman (Wightman, 1956) and Haag-Kastler (Haag, 1992) supply mature axiomatizations of relativistic quantum field theory in the closed-system regime. *Response.* We want to position the GG-Constitution relative to WH-K honestly: the two are *complementary frameworks at different scopes*, not competing axiomatizations of the same space. WH-K addresses closed-system QFT on a fixed background spacetime, with mature locality, covariance, and spectral conditions that have stood for half a century. The GG-Theory program extends the scope to include open dynamics (AX-3 OGGEP), a measurement compiler, and gauge-plus-geometry as axiomatic primitives (AX-1, AX-2); it does *not* replace the WH-K machinery in the closed regime, which the GG-Theory program inherits via T9 as a boundary-projection theorem. We acknowledge two further nuances. First, the WH-K axioms are not silent on theory-space structure — they fix a lattice of admissible closed QFTs satisfying their conditions — but they are silent on whether the continuous parameters that label points within that lattice are forced by a deeper principle; AX-4 MSMF and POS-6 OGN supply that further restriction. Second, the GKLS classification of admissible generators is not a discovery of the present paper; it is known mathematics from Gorini et al. (1976), Lindblad (1976). The axiomatic novelty is in treating GKLS as a forced admissibility class rather than as one effective formalism among many. We concede that the WH-K axioms have a longer track record of mathematical rigor, and the GG-Theory program owes them a debt.

Objection 5 (O-Constitution-5) (the philosopher of science)

"Calling something a constitution does not make it scientific. How is your axiom system different in kind from rationalist speculation?"

The philosopher of science, fluent in Popper, Kuhn, Lakatos, and Carnap, will object that any sufficiently elaborate axiom system can be made to "derive" a desired set of conclusions if its axioms are chosen well; the GG-Constitution is no different in kind from Spinoza's *Ethics* unless it ships with a falsification standard. *Response.* POS-7 MF is exactly that standard. Every theorem of the GG-Theory program is required to compile to a four-tuple $(\mathcal{I}, \mathcal{S}_{\text{valid}}, \mathcal{T}, K)$ of instrument, calibration window, timescale, and pre-declared kill criterion (Part III §20). The cross-paper coherence map of Table 6 and the consolidated falsifier table of Table 7 together supply the kill criterion for each Principal Theorem and the experimental status of every named numerical prediction. The constitution is structurally Popperian: a single 5σ deviation from any one of the canonical predictions falsifies the upstream constitutional clause. We concede that the philosophical distinction between "a constitution that predicts numbers" and "a constitution that postulates them" is a slippery one in practice, and that any working scientist will have to judge the GG-Theory program by its empirical record over the next decade. What makes a body of knowledge a science is not the cleverness of its calculations but the honesty of its rules; we have written the rules down, and we await contact with data.

Objection 6 (O-Constitution-6) (the string theorist)

"Your modified Bianchi identity and your Green–Schwarz inflow are exactly what we have been doing since 1984. What does the cohort actually add, and is it not just relabeled string theory?"

This is the most consequential objection the present paper must answer, and it deserves a careful response. The objection comes from the heirs of the Green–Schwarz construction and the modern AdS/CFT program, communities that have built four decades of spectacular mathematical machinery on top of the bulk-side classical-topological backbone the cohort framework also occupies. *Response.* We want to position the constitutional reading relative to string theory and AdS/CFT as carefully as honesty permits. In the cohort reading of POS-3 AF, the bulk-side $dX_4 = 0$ on the AX-2 GGEP composite connection *is* the same classical-topological identity that Green and Schwarz wrote down in 1984 as a B_2-coupled rewrite of Bianchi 1902. The constitutional reading does not pretend to have discovered Green–Schwarz; it claims, more modestly, that the Green–Schwarz identity is forced by AX-2 GGEP as a structural theorem, that the boundary 4D "anomaly" is the AX-3 OGGEP projection shadow of that bulk classical fact, and that string theory and AdS/CFT — to the extent that they share this bulk-side classical-topological backbone — are structural theorems under AX-2 (geometrization of gauge fields), not under the slogan "quantization of geometry." What the cohort *does not* subsume is the quantum-dynamical content that string theorists run on top of the classical backbone: graviton vertex operators, the α' and $1/N$ perturbative apparatus, the islands formula of Almheiri–Engelhardt–Marolf–Maxfield and Penington–Shenker–Stanford–Yang for the Page-curve recovery of unitarity from the black-hole interior, or the Gubser–Klebanov–Polyakov / Witten boundary-operator dictionary. Those constructions sit in the quantum-dynamical sector that the cohort axioms neither subsume nor contradict. Generally speaking, the cohort framework occupies the GGEP-closed sector — the classical-topological backbone — while the rich perturbative-string content lives in a separate physical sector that runs on top of the backbone we share. We concede readily that the bulk-side Hopkins–Singer differential-cohomology proof of (Arisaka, 2026, A3-BI6) owes much of its mathematical apparatus to decades of string-theory technical development, and we credit that lineage explicitly. What the cohort adds, and what we hope this paper makes precise, is the constitutional reading that *names* the bulk-side classical-topological backbone as a separate physical claim from the quantum-string content, so that the bulk side can be audited, falsified, and tested on its own without entanglement with the quantum-string sector's open questions. Part V of this paper develops the full constitutional-axiom classification: string theory and AdS/CFT both sit at the GGEP-closed stratum (Stratum-2 of the four-axiom tower), and the two famous limitations of string theory — the inability to derive the QM postulates and the $\sim 10^{500}$ vacuum landscape — are exactly the structural symptoms of working without AX-3 and AX-4. The cohort framework activates all four axioms explicitly and so produces the QM postulates as theorems and the unique vacuum from the integer OGN-5 ledger. Objection 12 below develops the single deepest structural sharpening of this point — *AdS/CFT is the closed-system limit of* OGGEP*, in the same sense that the Schrödinger equation is the closed-system limit of GKLS evolution* — which is the load-bearing identification that distinguishes Stratum 2 from Stratum 3 in the constitutional classification. See **Figure 10** and Table 8 for the full visual and tabular statement.

G The cohort architecture and how to read it

Objection 7 (O-Constitution-7) (the careful reader)

"If A1-Constitution proves nothing, what is the value of reading it? Cite-and-forward looks like evasion."

A particularly careful first-pass reader will notice that A1 names eleven Principal Theorems but proves none of them, and may reasonably ask whether the constitutional framing is more than rhetoric. *Response.* A1 is the rulebook; the cohort papers are the proofs. Constitutional documents in mature scientific practice — Euclid's *Elements* (which proves theorems from postulates), Newton's *Principia* (which proves the gravitational consequences of the three laws), Einstein's *Foundation of the General Theory of Relativity* (which proves the geodesic and field equations from the equivalence principle) — all share the discipline that the foundational document names the rules and proves their immediate consequences, not the entire downstream theorem space. A1 inherits this discipline. The eleven Principal Theorems are named at high level in A1 (Part IV §27.1) and their proofs live in the specific theorem locations of the cohort papers, with explicit pointers in the cross-paper coherence map (Table 6). We acknowledge that this is a strong demand on the reader: the reader who wishes to evaluate a specific claim must follow the pointer. We have made the pointers as specific as possible (theorem numbers, section numbers, page numbers where possible). The architecture is constitutional discipline, not evasion: an axiomatic document that included all eleven proofs would run to two thousand pages and would no longer be auditable at the constitutional layer. The cohort architecture is the price of keeping the constitutional document short enough to be read in an afternoon, while making every load-bearing claim trace to a specific cohort proof location. We invite the careful reader to follow the pointers for the specific objection they wish to raise; the companion papers are posted together precisely so that the proof is one click away.

Objection 8 (O-Constitution-8) (the time-constrained reader)

"What is the minimum reading combination required to evaluate this paper?"

A time-constrained reader will not work through twenty-two papers before forming a first opinion, and will reasonably ask which subset is required. *Response.* The minimum critical-reading set, depending on the reader's discipline, is named in the preamble of this section: A2+A3 for particle-physics / string-theory / quantum-gravity objections; A5+A8 for quantum-foundations / measurement-problem objections; A9+A10 for Standard-Model / cosmology objections. For a particle theorist whose immediate questions concern the integer OGN-5 ledger and the BI-6 trace-ratio lock, the two-paper read of A2+A3 is the minimum critical reading. For a quantum-foundations reader whose immediate question is whether the measurement-problem dissolution claim of A1 §11 Remark 1 is more than rebranded decoherence theory, the two-paper read of A5+A8 is the minimum critical reading. For a phenomenologist whose immediate question is whether the 28 Standard-Model parameters really collapse to zero or are quietly re-parametrized, the two-paper read of A9+A10 is the minimum critical reading. We acknowledge that this is still demanding compared to a single-paper review; the cohort is a substantial commitment. The twenty-one posted papers are posted together and reach arXiv in four staged submissions, so that an evaluator can follow the pointers without delay and the architecture is transparent from the first day rather than across a multi-year publication cycle. The capstone GG-A11-Origin is in preparation and is deliberately not in that set; nothing in the present paper depends on it.

Objection 9 (O-Constitution-9) (the senior community member)

"A twenty-two-paper program is too large for any single reader to evaluate. How is anyone supposed to judge this?"

A senior member of the community, with the breadth to attempt a full read, will object that no single human can rigorously evaluate twenty-two preprints in any reasonable time, and that the cohort architecture therefore defeats the peer-review function in practice. *Response.* We acknowledge the cost honestly, and address it three ways. First, the cross-paper coherence map (Part IV Table 6) pins every Principal Theorem Tk to a single specific proof location, so that any reader can target a specific claim and find its full proof in a single named place rather than searching across twenty-two papers. Second, the consolidated falsifier table (Part IV Table 7) consolidates every numerical falsifier into one place, with predicted value, observed value, comparison mode, pre-declared kill threshold, and experimental status as of writing; a reader who wishes to attack the cohort's empirical content can begin there. Third, the eleven A-papers form a tight forward-implication chain: A1 names the axioms; A2 proves the bulk theorems given A1; A3 proves the anomaly theorems given A2; A5 proves the boundary theorems given A2+A3; and so on. The chain can be read incrementally, with each paper building on the proved content of the upstream papers; a reader who has read A1+A2 can evaluate A3 without yet having read A5–A11. We acknowledge that no foundational program this ambitious has ever been published as a single coordinated cohort, and that the peer-review machinery will need to adapt to the architecture. The alternative — releasing the papers one at a time over five years, with the constitutional implications obscured by the long delay — is in our judgment worse for the community and for the science.

H String theory and the constitutional tower

Objection 10 (O-Constitution-10) (the working string theorist)

"Locating string theory at Stratum 2 of your four-Stratum tower is too aggressive. String theory has produced spectacular operational results — AdS/CFT correlators, the viscosity bound, the Ryu-Takayanagi formula, the islands formula for the Page curve — and these are operational results, not closed-system idealizations."

This is the working string theorist's instinctive defense of the program. *Response.* The cohort's Stratum-2 placement of string theory does not deny the operational results. Every result on the list above is preserved unchanged at Stratum 2 of the constitutional classification, because the GGEP-closed content (which is what Stratum 2 = $\{\mathsf{AX\text{-}1}, \mathsf{AX\text{-}2}\}$ is) is exactly the bulk-side classical-topological backbone within which those results are derived. Indeed, the islands formula (Almheiri et al., 2019, Penington et al., 2022) is, in the cohort reading, a boundary-side closed-system computation in which the *closed* unitarity of the bulk is restored at the cost of including non-local entanglement-wedge regions. The cohort framework inherits this result and credits it as a Stratum-2 theorem. What the cohort *adds* at Stratum 3 (with AX-3 OGGEP active) is the open-system extension to a finite boundary observer who registers discrete coarse quantum records — a regime that the closed-system holographic apparatus of AdS/CFT does not cover and was never designed to cover. See Objection 12 below for the deepest structural sharpening of this distinction.

Objection 11 (O-Constitution-11) (the senior theorist)

"Three of your four reasons that string theory cannot ascend beyond Stratum 2 are the same axiom (AX-4 MSMF) in three different dresses. That is not four independent reasons; it is one reason restated."

A careful senior theorist will notice that §35's "four-fold constitutional exclusion" of superstring theory — SUSY forbidden by AX-4, 10D/11D forbidden by AX-4, SO(32) / $E_8 \times E_8$ forbidden by AX-4, no constitutional measurement layer — compresses cleanly to two underlying constitutional gaps: the missing AX-3 (operational measurement) and the missing AX-4 (parsimony ordering principle). *Response.* The senior theorist is correct. We restate the four-fold exclusion honestly as the consequence of two missing axioms. String theory is missing AX-3 OGGEP, which would supply the operational measurement layer that turns boundary correlators into registered records; this is the structural diagnosis developed in Objection 12 below. String theory is missing AX-4 MSMF, which would forbid the unforced continuous freedom that produces SUSY-doubling, the 10D/11D dimensional choice, and the high-rank gauge groups. The three Stratum-2 "additions" the cohort framework rejects — SUSY, the 10D/11D bulk, and the

SO(32) / $E_8 \times E_8$ gauge content — are all consequences of the same missing AX-4 ordering principle. Calling them three separate reasons overstates the structural distance; the honest statement is that string theory lacks two of the four constitutional axioms (AX-3 and AX-4), and the three Stratum-2 additions are the textbook symptoms of the missing AX-4. We restate the exclusion as two reasons rather than four in §35, and we acknowledge the senior theorist's point as a sharpening of the cohort's claim, not as a refutation of it.

Objection 12 (O-Constitution-12) (the senior string theorist)

"AdS/CFT had OGGEP in 1998. The bulk-to-boundary holographic dictionary, the GKPW formula, and the operational matching of bulk fields to boundary correlators were all in place before you wrote the word OGGEP. Locating AdS/CFT at Stratum 2 because it lacks 'constitutional OGGEP' is therefore a renaming exercise — string theory had OGGEP in 1998, only it called it the holographic dictionary."

This is the deepest structural objection a senior member of the string-theory community will raise, and it deserves the most detailed response of the section. The objection is wrong, but the reason it is wrong is precisely what distinguishes Stratum 2 from Stratum 3 in the constitutional classification — and the response is the load-bearing structural payoff of the cohort framework. *Response.* The full answer is developed in (Arisaka, 2026, A5-GDOS) §6.4 ("AdS/CFT correspondence as the GGEP content on AdS solutions") and we summarize its content here in the form required for an A1-level audit.

The structural identification is:

$$\text{AdS/CFT} \;=\; \mathsf{OGGEP} \text{ at the AX-3-off limit;} \tag{170}$$

or, said the other way round, OGGEP is the open-system extension of AdS/CFT into the regime where the boundary observer is finite. The structural relationship between AdS/CFT and OGGEP is *exactly* the relationship between the Schrödinger equation and the GKLS master equation:

$$\text{Schrödinger (closed)} \xleftarrow{\gamma_k \to 0} \text{GKLS (open)}, \qquad \text{AdS/CFT (closed)} \xleftarrow{\textsf{AX-3 off}} \mathsf{OGGEP} \text{ (open).} \tag{171}$$

At the dynamical layer, Schrödinger evolution is the $\gamma_k \to 0$ closed-system limit of GKLS evolution; at the holographic layer, AdS/CFT is the AX-3-off closed-system limit of the cohort's OGGEP projection.

The technical core of the identification is the Stinespring dilation theorem. Every CPTP channel $\Phi : \rho \mapsto \Phi(\rho)$ admits a unitary representation on a system-plus-environment Hilbert space,

$$\Phi(\rho) \;=\; \mathrm{Tr}_{\mathrm{Env}}\big[\, U\,(\rho \otimes \sigma_{\mathrm{Env}})\, U^\dagger \,\big], \tag{172}$$

with U unitary. The "open" character of Φ comes *entirely* from the partial trace over the environment; in the no-environment limit, Φ degenerates to the bare unitary U. This is the universal sense in which closed-system unitary structure produces open-system CPTP structure once an environment is identified and traced out. For the cohort OGGEP-projection

$\mathcal{D}$: **Bulk** $\to$ **Op**, the boundary observer is the boundary slice of a larger bulk-plus-boundary system; the CPTP discipline on the boundary is enforced precisely because the bulk degrees of freedom (the "environment" of the boundary observer) are partially traced out. In the no-environment limit, where the boundary observer has access to the full bulk Hilbert space, the CPTP projection degenerates to a bulk-side unitary, and the OGGEP map degenerates to the AdS/CFT duality. The closed-system limit is therefore not a competitor to OGGEP; it is the AX-3-off corner of OGGEP.

The empirical content of the identification is the central physical claim: *there is no closed system in nature.* The boundary observer in any actual application of holography — the RHIC quark-gluon plasma viscosity measurement, the LHC heavy-ion data, the condensed-matter strange-metal correlator (Maldacena, 1998, Witten, 1998), the Page-curve experiments (Almheiri et al., 2019, Penington et al., 2022) — is, empirically, an open system. The observer has finite Hilbert-space dimension, finite integration time, finite spatial resolution, and finite measurement bandwidth. The boundary correlators that AdS/CFT computes are matched against open-system measurements at the moment the prediction is compared to data. AdS/CFT is therefore correct as the closed-system idealization but is *not* the actual physics governing the boundary record. The actual physics is OGGEP — the open-system extension of holography in which the boundary observer is finite, the projection is CPTP, the outcome is a discrete coarse quantum record, and the dual map is one-way rather than two-way.

This is the same diagnostic move that Zeh (Zeh, 1970), Joos–Zeh (Joos & Zeh, 1985), and Zurek (Zurek, 1981, 2003) made for quantum mechanics in 1970–2003, applied at the holographic layer rather than at the dynamical layer. The string-theory community has not yet absorbed the implications at the holographic layer because the closed-system idealization has been operationally adequate for the calculational targets the community pursues (correlators, viscosity bounds, entanglement entropies). The open-system extension becomes essential only when one asks: *how does a finite boundary observer actually register the prediction?* The cohort framework's claim is that the open-system extension is not optional — it is the actual physics — and that the closed-system holographic dictionary is therefore the AX-3-off corner of a more general operational framework.

Four properties of the boundary observer are absent from the closed-system AdS/CFT formulation and present in OGGEP:

(i) *Discrete* — instruments produce discrete outcomes $m \in \mathcal{M}$, not continuous amplitudes. AdS/CFT computes continuous correlators; only the CPTP discipline turns them into the statistical fingerprint of a registered record.

(ii) *Coarse* — the boundary observer has finite Hilbert-space dimension, integration time, and resolution. AdS/CFT assumes an idealized infinite-dimensional unitary CFT; the boundary observer in nature is finite.

(iii) *Sampling* — the boundary record is a sample drawn from a distribution that the bulk state determines, with outcome probabilities $p(m) = \mathrm{Tr}[\mathcal{I}_m(\rho)]$. AdS/CFT treats the Born rule as separately postulated; the cohort framework derives it as T7.3 of (Arisaka, 2026, A5-GDOS).

(iv) *Quantum* — the sampling is governed by CPTP / POVM / Stinespring discipline, with Bell-CHSH violation registered as a structural fingerprint of the bulk-side composite connection. AdS/CFT computes the Bell correlator but cannot derive its operational registration without invoking open-system content extra-axiomatically.

All four properties are properties of *nature*; all four are missing from the closed-system formulation of AdS/CFT. The cohort framework's claim is therefore precise: AdS/CFT has the bulk geometry and the conformal-boundary correlator structure correct; it is *missing* the operational discipline that turns those correlators into registered boundary records. The closed-system limit (AX-3 off) reproduces AdS/CFT exactly; the open-system content (AX-3 on) is what the cohort adds.

The empirical signature is testable. Because AdS/CFT is the closed-system limit, the cohort framework predicts that AdS/CFT will deviate from physical reality precisely in regimes where the boundary observer's open-system content matters: in low-statistics measurements, in single-shot experiments, in finite-resolution detectors, and in any holographic computation that asks "what does the boundary observer actually register?" rather than "what is the correlator?" These deviations are the empirical content of moving from Stratum 2 to Stratum 3. The Bell-CHSH violation derived as T7.7 of (Arisaka, 2026, A5-GDOS) is the sharpest example; the textbook QM postulates derived as the T7.1–T7.7 chain are the structural payoff.

Summary. AdS/CFT had the closed-system limit of OGGEP in 1998. What AdS/CFT did not have, and what the cohort adds, is the open-system extension that turns boundary correlators into registered records — the discipline that *makes the holographic dictionary apply to the actual finite boundary observers that perform measurements in nature.* This is not a renaming. It is the structurally most consequential sharpening of the holographic dictionary since the original 1997 formulation, and it is the load-bearing technical content of AX-3 OGGEP in the constitutional reading.

I Methodology: axioms, ordering, and the integer ledger

Objection 13 (O-Constitution-13) (the philosophy-of-physics specialist)

"AX-4 MSMF is essentially Occam's razor elevated to a postulate. Is this physics or aesthetics?"

A philosopher of physics fluent in model-selection theory will object that AX-4 reads like the standard Occam-razor heuristic restated as a constitutional axiom, and that the right scope for parsimony is methodological (Akaike, Rissanen, Bayesian model comparison) rather than constitutional. *Response.* We acknowledge the structural neighborhood with Occam's razor and sharpen the distinction. Occam's razor is a methodological preference for simpler models among observationally equivalent alternatives; AX-4 MSMF is the precise constraint that an admissible theory have *zero free continuous parameters* at the constitutional level. The physical motivation is the predictivity constraint: a theory with free continuous parameters cannot predict the actual values its parameters take, because any observed value can be accommodated by tuning. AX-4 elevates the predictivity constraint to a constitutional axiom: an admissible theory must commit to specific numerical content, leaving none of it adjustable. This is not arbitrary preference; it is the constitutional condition for the theory to be predictive of the world rather than fittable to it. See (Arisaka, 2026, A3-BI6) Common Objection 12 for the parallel statement at the BI-6 level. We acknowledge that not every physicist will accept the elevation as constitutional — some will reasonably take the view that AX-4 is a strong methodological commitment that the cohort framework chooses to make and that other frameworks may decline. The cohort program stands by the commitment because the resulting predictions ($M_{\text{lock}} \approx 3.85$ TeV, $\Omega_m = 1/\pi$, kaxion at ~ 8.1 μeV, the integer OGN-5 ledger, the 28-to-zero parameter compression of the Standard Model) are sharp enough to be falsified within the 2026–2040 horizon. If the predictions fail, AX-4 will have been shown to be the wrong constitutional commitment, and the framework will have been refuted upstream.

Objection 14 (O-Constitution-14) (the careful Diophantine analyst)

"The OGN-5 uniqueness theorem you cite from GG-A2-GG6 depends on the AX-4 lexicographic ordering. Under other orderings, the Diophantine system admits other integer tuples. How is this not a hidden choice?"

A careful analyst who reads Theorem 3 of (Arisaka, 2026, A2-GG6) will notice that the Diophantine system $K = LJ = M^2 + N^2 + L^2$ with $J = 2N + 1$ admits the integer family $(L, N) = (5k, 3k)$ for any positive integer k, and that the selection of $k = 1$ comes from the AX-4 minimality requirement, not from the Diophantine system alone. *Response.* This is correct and is explicitly acknowledged in both GG-A2-GG6 and in (Arisaka, 2026, A3-BI6) Common Objection 8. The AX-4 minimum-dimensional-rank requirement is the load-bearing constraint that selects $k = 1$ out of the integer family, and we are explicit that this is an axiomatic input rather than a Diophantine output. Honest restatement: OGN-5 uniqueness is the joint consequence of two axiomatic inputs — the Diophantine system and the AX-4 ordering — not of the Diophantine system alone. Removing either input opens up the integer family; with both, the family collapses to the unique five-tuple $(1, 3, 5; 7, 35)$. The AX-4 ordering is not hidden; it is the explicit content of the MSMF axiom in Part II §8 and is named in every uniqueness claim the cohort framework makes. A reader who finds the AX-4 ordering insufficiently motivated can reject it; the cohort framework's uniqueness claim is then weaker but the architecture remains. We acknowledge that a more thorough ordering-independent analysis — exhibiting all admissible orderings, computing the OGN tuple under each, and showing that the empirical OGN-5 $= (1, 3, 5; 7, 35)$ is favored by data under all admissible orderings — would substantially strengthen the uniqueness claim. This is recorded as Open Problem O9 of the cohort program.

J Phenomenology, cosmology, and falsifiability

Objection 15 (O-Constitution-15) (the phenomenologist)

"Three fermion generations following from $N = 3$ in the OGN-5 ledger is exactly the kind of numerology that has misled physicists for a century. Replacing 'we observe three generations' with 'we postulate $N = 3$ and the constitution forces three generations' is not a derivation."

A phenomenologist whose career has been spent making the empirical world fit into theoretical structures will object that matching an observed integer with an axiomatically labeled integer is not a derivation but a coincidence. *Response.* The cohort framework agrees that "picking $N = 3$ to match an observed integer" would be numerology; it is not what the framework does. Two clarifications are owed before the answer, and both narrow the claim. First, N is the *color* triplicity index N_c, not the number of fermion generations N_g; the latter is not a member of this ledger and is settled elsewhere (Arisaka, 2026, P2-N3), so the objection's pairing of N with the generation count is not the framework's. Second — and this is the substance — $N_c = 3$ is *not* derived from the trace-ratio lock $(L - N)/L = 2/5$. That ratio is computed on the 3+2 split of the defining representation, so deriving N from it would assume what it concludes, and the framework does not use it that way. What forces $N_c = 3$ is the dual lock $K = LJ = M^2 + N^2 + L^2$ with the closure-index clause $J = 2N + 1$: it gives $N = L \pm \sqrt{L - M^2}$, and at the $L = 5$ fixed independently and free of N by (Arisaka, 2026, A3-BI6) Theorem T-BI6-9.0, the roots are 3 and 7, of which the block embedding $N < L$ retains 3 (Arisaka, 2026, A3-BI6, Theorem T-BI6-10.2a). No observed quantity enters the chain, which is precisely what distinguishes it from the numerology the objection has in mind. The integer $N = 3$ is therefore not an independent input chosen to fit data; it is a derived consequence of the four-component anomaly polynomial structure that the cohort framework constitutionally forces. See (Arisaka, 2026, A3-BI6) Common Objection 8 for the parallel statement and the explicit derivation chain. The three-generation observation is then a *consequence* of the OGN-5 ledger, not a fitted input. We acknowledge honestly that a reader who has not followed the trace-ratio derivation in GG-A3-BI6 will reasonably see the $N = 3$ match as suspicious; that is precisely why the cohort architecture requires the trace-ratio derivation to live in a separately publishable cohort paper rather than be asserted in A1. The minimum critical-reading set for this objection is A2 + A3; once the trace-ratio lock and the minimum-dimensional-rank ordering are both read, the $N = 3$ match becomes a structural prediction rather than a numerological coincidence.

Objection 16 (O-Constitution-16) (the cosmologist)

"$\Omega_m = 1/\pi$ is, on the face of it, numerology. Eddington's 1929 derivation of the fine-structure constant from 137 was numerology; Dirac's large-number hypothesis was numerology; show me why this is different."

A cosmologist with the history of failed numerological matches in mind will reasonably demand that the $\Omega_m = 1/\pi$ agreement (Planck 2018 $\Omega_m = 0.3153 \pm 0.0073$ vs the cohort prediction

$1/\pi \approx 0.31831$, agreement at $\sim 0.3\sigma$) be demonstrated as a structural consequence rather than a coincidence. *Response.* The full derivation lives in (Arisaka, 2026, A10-Cosmos). The key honest statement: the cohort framework predicts *four* cosmological partitions simultaneously from one consistent bulk-geometry calculation,

$$\Omega_m = \frac{1}{\pi}, \qquad \Omega_\Lambda = 1 - \frac{1}{\pi}, \qquad \Omega_b = \frac{1}{2\pi^2}, \qquad \Omega_{\rm DM} = \frac{1}{\pi} - \frac{1}{2\pi^2}, \tag{173}$$

not from four separate fitting exercises whose results happen to sum to one. The four partitions descend from one geometric integral over the 6D bulk; the rational fractions are forced by the OGN-5 integers (the integer $35 = K = LJ$, the integer 2π = holonomy circle period) and the bulk boundary conditions. The structural test is whether the four partitions all match data simultaneously: $\Omega_m = 1/\pi$ at 0.3σ, $\Omega_b = 1/(2\pi^2)$ at $\sim 2\sigma$, and the sum constraint $\Omega_m + \Omega_\Lambda = 1$ exactly. If the cohort framework were post-hoc curve-fitting, the four partitions would not all fall out of one calculation. The kill threshold consolidated in Part IV Table 7 is sharp: a registered 5σ deviation from $1/\pi$ in any next-generation cosmology dataset (CMB-S4, LiteBIRD, DESI) at resolution $\sigma_{\Omega_m} \leq 0.003$ collapses AX-4 + POS-6 + T8 jointly. We acknowledge that the prediction's pre-history — whether it was a derivation made before the Planck 2018 data were matched, or after — is itself relevant; the published cohort archive (arXiv submission date) fixes the public record.

Objection 17 (O-Constitution-17) (the LHC phenomenologist)

"$M_{\rm lock} \approx 3.85$ TeV is not a complete prediction. What is the state's spin? What is its production cross-section? What channel does it decay into? Without these, the LHC cannot test it."

An LHC phenomenologist whose work consists of comparing BSM predictions to ATLAS and CMS bounds will object that a TeV-scale mass without specified couplings is half a prediction. Current LHC limits exclude generic Z' resonances above ~ 5 TeV in dilepton, RS-class KK gravitons above ~ 4.5 TeV in diphoton, and stringy resonances above ~ 5–7 TeV depending on coupling (Particle Data Group, 2024). A 3.85 TeV state is therefore either already constrained or already discovered, depending on what it is. *Response.* The LHC phenomenologist is correct: the $M_{\rm lock}$ entry of Part IV Table 7 requires augmentation with the specific quantum numbers of the predicted state. The full specification lives in the Predictions Branch paper GG-P1-KK (Arisaka, 2026, P1-KK), which derives the production channel, the spin, the color assignments, and the branching fractions from the Kaluza-Klein lock-cluster structure of the 6D bulk of GG-A2-GG6. We acknowledge that the current falsifier-table entry "Active LHC search" is incomplete without these specifications, and we forward the LHC phenomenologist to GG-P1-KK for the full claim contract. The constitutional discipline is honest: a TeV-scale mass without specified couplings is not a POS-7 MF-compliant claim, and the cohort archives the full specification in GG-P1-KK rather than smuggling it into A1.

Objection 18 (O-Constitution-18) (the precision physicist)

"$\alpha^{-1}(0) = 137$ matches the empirical value at the integer level, but the precision

measurement is 137.036. Either the cohort framework predicts the full value with the 0.036 correction, or the integer-only match is numerology."

A precision physicist will demand that a four-decimal-place empirical match be addressed at four-decimal-place precision. *Response.* Direct parallel to (Arisaka, 2026, A3-BI6) Common Objection 14. The integer 137 is the leading-order constitutional prediction; the 0.036 correction comes from higher-order vacuum-polarization thresholds in (Arisaka, 2026, A8-QM) and the renormalization-group running in (Arisaka, 2026, A9-SM). The cohort framework predicts $\alpha^{-1}(0) = 137 +$ (specific higher-order corrections); the integer alone is not the full prediction. We do not claim the integer 137 as a stand-alone identity; we claim the leading-order integer plus the derived corrections, with the full quantitative comparison to the empirical $\alpha^{-1}(0) \approx 137.036$ carried out in (Arisaka, 2026, A9-SM). The minimum critical-reading set for this objection is A8 + A9; once the higher-order corrections are read, the 137 match becomes a derived structural prediction rather than a numerological coincidence.

Objection 19 (O-Constitution-19) (the decoherence-theory veteran)

"AX-3 OGGEP is decoherence theory relabeled. Zeh 1970, Joos-Zeh 1985, and Zurek 1981/2003 made the same operational move forty years ago; the einselection program derives the textbook Born rule as a consequence of environment-induced superselection. What is the new content?"

A veteran of the decoherence program will object that AX-3 inherits the einselection insight without adding new derivation content. *Response.* We acknowledge the structural neighborhood with decoherence theory and sharpen the distinction. The decoherence program is a derivation: given specific model Hamiltonians and environments, the Born rule and the preferred pointer basis emerge as derived asymptotics on the einselection timescale. AX-3 OGGEP is a constitutional move: "every system in nature is an open system" is elevated from a derived consequence in specific models to an axiomatic statement that applies universally. The novelty is not the decoherence mechanism (which the cohort framework inherits); the novelty is the constitutional status. The technical content of the T7.1–T7.7 derivation chain of (Arisaka, 2026, A5-GDOS) is the substantive payoff: the Born rule (T7.3), the Lüders projection (T7.4), the einselection preferred basis (T7.6), and the Bell–CHSH violation (T7.7) all emerge as *theorems* of AX-3 + POS-4 acting on the bulk, not as separate measurement postulates. The decoherence program produces these results in specific models; the cohort produces them as constitutional theorems. The operational claim of A1 §11 Remark 1 — "the century-old measurement problem is finally solved by AX-3 OGGEP" — is therefore not the claim that the cohort discovered decoherence. It is the claim that the cohort elevates the decoherence insight from one effective treatment of measurement to the constitutional definition of measurement. Cross-cite (Arisaka, 2026, A5-GDOS) Part III for the T7.1–T7.7 chain; cross-cite (Arisaka, 2026, A8-QM) for the textbook reformulation in GG-Theory language.

Objection 20 (O-Constitution-20) (the swampland theorist)

"Your AX-4 MSMF + POS-6 OGN is the strongest possible parsimony commitment. The swampland program (Vafa 2005 and successors) does similar structural work via a

menu of conjectures (weak-gravity, distance, de Sitter, cobordism). How does the cohort framework relate to the swampland?"

A swampland theorist who has spent the last fifteen years sharpening the swampland conjectures will reasonably demand that the cohort framework engage with the swampland program as a parallel research effort. *Response.* Direct parallel to (Arisaka, 2026, A3-BI6) §11 ("Swampland compatibility of GG-6 and BI-6"). The cohort framework checks against the five most widely accepted swampland conjectures and reports the result honestly: four (no global symmetries, completeness, distance, cobordism) are satisfied at the structural level; one (weak-gravity) is structurally compatible with the quantitative check deferred to the boundary spectrum derivation in GG-A5-GDOS, GG-A7-Qi4, and GG-A9-SM. The de Sitter conjecture is omitted because its status as a universal constraint is itself disputed in recent literature; the cohort cosmological inventory lives in GG-A10-Cosmos. The cohort framework is therefore in the landscape rather than the swampland by the most widely accepted criteria. The structural relationship between AX-4 MSMF and the swampland conjectures: where the swampland says "not every EFT is consistent in quantum gravity," AX-4 says "the admissible EFT is the unique lexicographic maximum of the constitutional Diophantine system." The cohort's commitment is strictly stronger than the swampland's: instead of a menu of conjectures, one constitutional axiom forbids all unforced continuous freedom. We acknowledge that this is a stronger claim; the cohort's empirical predictions ($\Omega_m = 1/\pi$, $M_{\text{lock}} \approx 3.85$ TeV, kaxion $\Delta\nu/\nu = 1/35$) are the burden that the stronger claim must carry. Detailed swampland verification (WGC saturation, cobordism enumeration) lives in (Arisaka, 2026, A3-BI6) §11 and is recorded as Open Problem.

Objection 21 (O-Constitution-21) (the quantum-gravity generalist)

"You compete with the swampland. What about asymptotic safety (Reuter 1998 and successors) and emergent gravity (Verlinde 2011, Padmanabhan 2010)? Where do these fit in the constitutional classification?"

A quantum-gravity generalist will reasonably demand that the constitutional framework name its competing programs explicitly. *Response.* Asymptotic safety (Reuter, 1998) is a Stratum-2 alternative: it accepts gauge-covariant gravity (consistent with AX-2 GGEP in the closed-system regime) and uses the renormalization-group flow (consistent with POS-5 RG) to claim a UV-complete non-Gaussian fixed point. Asymptotic safety does not yet activate AX-3 OGGEP (no constitutional operational layer) or AX-4 MSMF (no constitutional parsimony commitment), so it sits at Stratum 2 in the constitutional tower alongside string theory and AdS/CFT. The cohort framework is not in conflict with asymptotic safety at the kinematic level; it adds the operational extension (Stratum 3) and the parsimony commitment (Stratum 4) that asymptotic safety does not address. Emergent / entropic gravity (Padmanabhan, 2010, Verlinde, 2011) is, by contrast, *directly incompatible* with AX-2 GGEP: where the cohort takes geometry as primitive and gauge as composite, emergent gravity takes geometry as derived from thermodynamics (or from entanglement entropy in the holographic version). This is a structural fork. The cohort framework names this disagreement as a fundamental constitutional fork, not as an incidental detail: AX-2 picks one side of the fork, emergent gravity picks the other. The empirical content of the choice is testable wherever the cohort's specific quantitative predictions ($\Omega_m = 1/\pi$, $M_{\text{lock}} \approx 3.85$ TeV, the kaxion oscillation at 1/35) hit data: if the cohort's predictions verify, AX-2 wins; if they fail, the emergent-gravity alternative gains ground. We acknowledge that some readers will find the geometry-primitive commitment less natural than the geometry-emergent stance. The cohort framework's response is that the constitutional commitment is testable, and the next decade of cosmological and TeV-scale data will adjudicate.

K Scope: information, life, and cross-domain reach

Objection 22 (O-Constitution-22) (the complex-systems biologist)

"Your energy–information Arisaka constant $\mathsf{Q_B} \approx 0.156$ eV per qubit, multiplied by Avogadro's number, gives ~ 15 kJ/mol. How does this map onto the biological energy currency?"

This is the kind of detail a biologist catches on first read. *Response.* $\mathsf{Q_B}$ is the per-qubit energy–information unit of the boundary $\mathrm{U}(1)_{Qi}$ current; its calibration against the biological energy currency — the per-qubit stoichiometry and its standard-versus-cellular corrections — is the empirical anchor developed in (Arisaka, 2026, A7-Qi4; Arisaka, 2026, A11-Origin) and is not part of the geometric construction of the present paper. The constitutional claim is that $\mathsf{Q_B}$ supplies the *quantum-information bit energy* of the boundary current, with the empirical mapping onto the biological currency carried in those companions.

Objection 23 (O-Constitution-23) (the computational neuroscientist)

"Your claim to dissolve the hard problem of consciousness by structural stipulation is too quick. That is renaming the problem, not solving it."

This is correct and we accept the criticism in the form stated. *Response.* The constitutional framework does not claim to *solve* the hard problem of consciousness in the sense of closing the explanatory gap that Chalmers (1995), Block (1995), and Strawson (2006) articulate. (Arisaka, 2026, A11-Origin) adopts a *Russellian neutral-monism stipulation* at each GRIP event in the eighteen-layer cascade: the layered identities (electron, atom, molecule, ATP, RNA, DNA, cell, eukaryote, brain, conscious episode) are events on the same lawful state manifold, and the phenomenal aspect appears as a structural feature of sufficiently deep GRIP events rather than as an additional metaphysical ingredient. This is a philosophical *position* in the lineage of Russell (1927), Stoljar (2006), and Strawson (2006), not a *proof.* What the framework adds beyond pure philosophy is structural distinguishability: the eighteen-layer cascade carries specific empirical predictions in (Arisaka, 2026, A11-Origin) that distinguish it from Friston's free-energy principle, integrated-information theory, and global workspace theory at the level of neural observables. The honest position is therefore that the cohort framework offers a *structural account* of where consciousness sits in the lawful cascade — which is empirically constrained — and a *philosophical stipulation* of what the phenomenal aspect is — which is not empirically constrained. We make both layers explicit so that readers in philosophy of mind and in neuroscience can engage with each on its own terms.

Objection 24 (O-Constitution-24) (the philosopher of physics)

"What is the metaphysical status of AX-4 MSMF? It does most of the heavy lifting — forcing OGN-5 uniqueness and collapsing the string landscape — yet its philosophical foundation is not articulated."

This is the deepest single criticism of the constitution from the philosophy-of-physics direction, and it deserves an explicit answer. *Response.* AX-4 MSMF is a *constitutional commitment*, not a metaphysical claim about Nature. It states: among admissible bulk theories, prefer the one of maximal symmetry and minimal continuous freedom, under an explicit lexicographic ordering (maximize symmetry first, minimize freedom second). In its philosophical lineage this clause descends from William of Occam's *numquam ponenda est pluralitas sine necessitate* (c. 1320s) through Mach's relational principle (*Science of Mechanics*, 1893) to Einstein's 1933 Herbert Spencer Lecture ("the supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction"). AX-4 promotes that philosophical preference from *methodological heuristic* to *constitutional filter*: where the preceding three axioms admit a continuous family of solutions, AX-4 selects the lexicographic maximum. This is *normative-but-falsifiable*: if a second admissible bulk theory is found under the same Diophantine system and the same ordering but with equal predictive power and lower symmetry, AX-4 fails and the constitution falls. The reader who wishes to defend a different normative ordering (AX-4′) is free to do so; what the constitution forbids is the silent use of an ordering without naming it. See (Arisaka, 2026, A4-Euclid) for the extended philosophical argument that locates AX-4 in the long Euclidean tradition of admissibility-by-rulebook rather than admissibility-by-data.

Objection 25 (O-Constitution-25) (the cross-domain reader)

"You claim the same four axioms organize the proton and the conscious moment. This is either the deepest empirical regularity ever stated, or a category error. Which is it?"

We accept that this is the most contestable claim of the program, and we state the honest answer. *Response.* It is a *structural claim about a program of inquiry*, not a settled empirical regularity. The twenty-two-paper cohort develops the eighteen-layer GRIP cascade in (Arisaka, 2026, A11-Origin) as a sequence of forced identities — gauge symmetry breaking → atomic ground state → molecular bonding → ATP energy quantum → RNA → DNA → first cell (LUCA) → eukaryogenesis → neural integration → conscious episode — each layer a theorem of the same axiomatic system applied at a different stratum. Each layer carries a specific empirical prediction with a specific live falsifier; the framework is therefore empirically distinguishable layer by layer. If the cascade fails at any layer — if the Q_B value disagrees with its energy–information calibration ((Arisaka, 2026, A7-Qi4; Arisaka, 2026, A11-Origin)), if the developmental-timing predictions disagree with embryology, if the neural-integration prediction disagrees with the cortical-rhythm data — the failure is locatable and the universal-identity claim shrinks to whatever layer survives. The framework is therefore neither a settled result nor a category error; it is a *disciplined program* with twelve to seventeen explicit falsifiers, and its scope shrinks or expands by the next decade's experiments. The honest position is that we do not know whether the four axioms truly organize the long sequence of identities, and we have written down the specific tests by which the question can be settled.

Objection 26 (O-Constitution-26) (the bio/neuro phenomenologist)

"To be evaluated by the complex-systems biology and computational neuroscience community, your framework needs specific quantitative predictions that distinguish it from Friston's free-energy principle, Tegmark's integrated information theory, and Baars-Dehaene global workspace theory."

This is correct and the requirement is fair. *Response.* (Arisaka, 2026, A11-Origin) carries the specific predictions that distinguish the GRIP cascade from the three named alternatives. Among them: (i) the $\mathsf{Q_B}$-mediated energy–information calibration described in Objection 22 above, which is quantitative and empirically tight; (ii) specific developmental-timing predictions at the cell-division layer, keyed to the integer $K = 35$ of the OGN-5 ledger; (iii) a specific spectral signature in cortical gamma-band activity at frequencies ν_{GG} predicted by the neural-integration layer of the cascade, distinct from the 40 Hz central frequency of the binding-by-synchrony framework; (iv) a specific information-integration coefficient that distinguishes the cascade prediction from the Φ coefficient of IIT. Each prediction carries a 5σ kill criterion in (Arisaka, 2026, A11-Origin); specific failures collapse specific GRIP layers without collapsing the constitutional core (the upstream axioms). We acknowledge that the bio/neuro community will require independent reproduction of each prediction before accepting the cascade. The cohort framework welcomes this scrutiny: the discipline of the constitution is that any specific failure is locatable, not that the framework is correct.

L The four axioms: independence, necessity, and minimality

Objection 27 (O-Constitution-27) (the axiomatic-systems theorist)

"Are the four axioms genuinely independent? An axiom that is a theorem of the others is not an axiom."

Response. Independence is argued in the inter-axiom analysis (§9) and summarized in the axiom table (§10): each clause is load-bearing because dropping it removes a class of admissible structure the others cannot restore. Without AX-1 (LC) the local-field arena is lost; without AX-2 (GGEP) the geometry and gauge sectors decouple and the 6D bulk is no longer forced; without AX-3 (OGGEP) the closed bulk has no boundary law, hence no measurement or thermodynamic content; without AX-4 (MSMF) the moduli return and uniqueness fails. The constitutional tower (§29) makes this operational: every existing framework sits at the level of the axioms it uses, and the missing axioms predict its missing structure. None is a theorem of the others, which is exactly the test the objection demands.

Objection 28 (O-Constitution-28) (the skeptic)

"MSMF (AX-4) is circular: you call whatever the framework derives 'minimum freedom.' How is it a constraint rather than a label applied after the fact?"

Response. MSMF is stated as a constraint with teeth *before* any result is derived (§8): it forbids any continuous parameter or modulus not fixed by an explicit constitutional clause, and demands the maximal symmetry consistent with the other axioms. Its non-circularity shows in what it *excludes* in advance — the string landscape's moduli, a free compactification radius, any tunable coupling — each a concrete structure other frameworks permit and MSMF forbids (§33, the vacuum count). A label applied after the fact cannot exclude anything beforehand; MSMF removes the moduli space before the integer ledger is derived. Its bite is measured by the freedom it removes, not by the results it later names — and that removal is the step that turns "a geometry consistent with the data" into "the unique geometry."

Objection 29 (O-Constitution-29) (the relativist)

"AX-1 (Local Causality) is assumed by all of physics. It does no discriminating work — why elevate a triviality to a founding axiom?"

Response. AX-1 is not there to discriminate among modern theories — nearly all respect it — but to fix the *arena* in which the other axioms operate and to forbid the non-local shortcuts that an extra-dimensional construction could otherwise smuggle in (§5). Its work is constraint at the boundary: it is what guarantees that the two non-spatial dimensions of the 6D bulk carry no faster-than-light signaling, so that the geometry–gauge equivalence of AX-2 does not violate causality (§9). A founding charter must state even the conditions everyone assumes, precisely so that a later step cannot quietly drop them; AX-1 is the clause that the OGGEP boundary projection and the 6D bulk are held to. Triviality among 4D theories is not triviality once extra structure is admitted.

Objection 30 (O-Constitution-30) (the gauge theorist)

"AX-2 says geometry and gauge are equivalent. Is that a definition, a conjecture, or a theorem? If a definition it is empty; if a conjecture it is unproven."

Response. It is an *axiom* — a stated principle taken as primitive, exactly like the equivalence principle in general relativity, which is also neither a definition nor a theorem but a posited identity whose justification is the structure it forces (§6). GGEP posits that the frame/spin connection and the internal gauge connection are components of one composite connection. That is not empty: it has the falsifiable consequence, proved in the companion papers, that the modified Bianchi identity BI-6 locks gravitational and gauge anomalies together (Arisaka, 2026, A3-BI6), and that the bulk gauge content is fixed rather than chosen (Arisaka, 2026, A2-GG6). So the status is: posited here, its consequences proved downstream, and the whole standing or falling on whether those consequences hold (§27). An axiom is judged by its yield, not by being a theorem of something prior.

Objection 31 (O-Constitution-31) (the foundations theorist)

"Why exactly four axioms? Why not three, by dropping one, or five, by adding one? Is

four forced or aesthetically chosen?"

Response. Four is the minimal independent set that closes the construction, and the paper shows the closure rather than asserting the number (§9, §10): AX-1 fixes the arena, AX-2 unifies geometry and gauge, AX-3 opens the system to a boundary law, AX-4 removes residual freedom. Drop any one and a named class of results disappears (Objection 27); add a fifth and, by MSMF itself, it must either be derivable from the four — hence not an axiom — or introduce freedom the construction forbids. The four therefore are not an aesthetic choice but the answer to "what is the smallest rule-set that forces a unique, anomaly-free, measurable theory?" The honest qualifier: minimality is a claim about *this* construction, argued in §9, not a proof that no other four-clause system exists.

Objection 32 (O-Constitution-32) (the logician)

"Your axioms rest on undefined primitives — 'geometry,' 'gauge,' 'openness,' 'freedom.' An axiom system built on undefined terms proves nothing."

Response. The primitives are defined, in the working-definitions section that opens the formal development (§1.5) and in the shared mathematical arena the axioms inhabit (§4.1): "geometry" is the six-dimensional manifold with its metric and connection, "gauge" the principal-bundle connection, "openness" the finite-resolution boundary projection of OGGEP, and "freedom" a continuous modulus or coupling not fixed by a clause. These are the same primitives modern geometry and gauge theory already use; the constitution does not invent new undefined notions, it commits to specific instances of standard ones. Where a term is program-specific (GDOS, the integer ledger), it is forwarded to the companion paper that constructs it (§27). So the system is not built on undefined terms; it is built on standard mathematical objects with their definitions stated up front.

Objection 33 (O-Constitution-33) (the philosopher)

"Who decides what is 'admissible'? An admissibility predicate is just your preferences elevated to law."

Response. The predicate is fixed, public, and applied uniformly, which is the only defense any framework can offer and the reason the paper states it explicitly so it can be contested (§13.1, §1.5): a theory is admissible iff it satisfies the eleven clauses, each a checkable condition. The check against "mere preference" is that the predicate *discriminates*: run against general relativity, gauge theory, string theory, quantum mechanics, the Standard Model, and ΛCDM it returns a different axiom-subset for each (§32), and it rules inadmissible any formulation carrying free moduli — including formulations of *this* program's own content that do. A predicate that admitted whatever the author liked could not separate frameworks, nor exclude versions of its own program. Preferences enter only in choosing *which* clauses to adopt — and those are on the page, falsifiable by their consequences, not hidden.

M The seven postulates and the axiom/postulate split

Objection 34 (O-Constitution-34) (the methodologist)

"Why split the rules into four axioms *and* seven postulates? The distinction looks arbitrary — relabel and you have eleven axioms."

Response. The split is principled, not cosmetic, and the paper states the principle (§1.4, §13.1): the four axioms are the always-on commitments that define the arena and the geometry–gauge–openness structure; the seven postulates are runtime admissibility filters that a *candidate Lagrangian* must pass once the arena is fixed (anomaly freedom, closure/positivity, RG-compatibility, and so on). Axioms say what kind of object a theory is; postulates say which such objects survive. Collapsing them into "eleven axioms" would lose the operational distinction that makes the constitution usable as a filter — you would no longer know which clauses constrain the construction and which screen the output. The dependency chain among the postulates (§21) shows they form an ordered filter, not a second pile of axioms.

Objection 35 (O-Constitution-35) (the skeptic)

"Seven postulates is a suspiciously resonant number. Is seven forced, or chosen for effect?"

Response. Seven is the number of independent runtime filters the construction actually needs, enumerated and ordered in the postulate dependency chain (§21) and tabulated in §24; it carries no numerological weight and is not tied to the integer ledger (which lives in GG-A3-BI6 (Arisaka, 2026, A3-BI6), not here). Each postulate is defended by what fails without it: drop anomaly freedom (POS-3) and the quantum theory is inconsistent; drop closure/positivity (POS-4) and probabilities go negative; drop RG-compatibility (POS-5) and the scale structure breaks. If a future analysis showed two postulates were equivalent, the count would honestly drop to six — the number is an output of the enumeration, not a target. We make no claim that "seven" is itself significant; the significance is that each filter is necessary and the set is complete for admissibility.

Objection 36 (O-Constitution-36) (the axiomatic-QFT specialist)

"POS-3 (anomaly freedom by inflow) is a standard consistency condition, not a 'postulate.' Dressing consistency requirements as postulates inflates the count."

Response. POS-3 *is* a consistency condition — the paper does not claim otherwise (§16); what makes it a postulate of *this* constitution is that it is promoted to an admissibility filter that any candidate must pass *and* given a specific geometric realization (anomaly cancellation by inflow from the bulk, the Green–Schwarz mechanism elevated to a constitutional clause and proved for BI-6 in Arisaka (2026, A3-BI6)). The objection is right that, viewed from ordinary QFT, anomaly freedom is mandatory; the constitutional move is to make it a *stated* clause rather than an implicit assumption, so that the eleven-clause filter is complete and self-contained. That is the opposite of inflation: it is refusing to leave a load-bearing requirement unstated. The count reflects the filters a candidate must pass, and anomaly freedom is genuinely one of them.

Objection 37 (O-Constitution-37) (the renormalization-group theorist)

"POS-5 (RG-compatibility) is just a property any sensible quantum field theory already has. Why postulate it?"

Response. It is postulated because the construction makes the renormalization-group scale a genuine *geometric direction* (the scale/RG interval of the bulk), so RG-covariance is not automatically inherited — it must be imposed as the condition that the 4D effective theory be covariant under flow along that direction (§18). In ordinary 4D QFT, RG-compatibility is indeed a background property; here it is the clause that ties the fifth dimension to the renormalization group and forbids constructions in which the scale direction and the RG flow disagree. So POS-5 does work that "any sensible QFT" does not require: it constrains how the extra-dimensional geometry projects to four dimensions. The honest point the objection contains is that, restricted to the 4D output, POS-5 looks standard — but its constitutional role is upstream, at the bulk-to-boundary reduction.

Objection 38 (O-Constitution-38) (the foundations theorist)

"Are the postulates testable? If POS-4 (closure and positivity) is violated, what experiment shows it — or is it unfalsifiable by construction?"

Response. The postulates are testable indirectly, through the theory they admit: POS-4 (closure/positivity, §17) is the clause that forces completely-positive boundary dynamics, and a violation would show up as negative probabilities or non-unitary evolution in the quantum sector — which is exactly what the measurement and QFT derivations of the companion papers reproduce as standard QM, and which any experiment confirming the Born rule and CPTP channels confirms in turn (Arisaka, 2026, A5-GDOS; Arisaka, 2026, A8-QM). A postulate is not falsified in isolation; it is falsified through the empirical failure of the construction it licenses. The sharp falsifiers are downstream and named (the 3.85 TeV resonance (Arisaka, 2026, P1-KK), proton decay, the π-locked cosmic inventory (Arisaka, 2026, A10-Cosmos)). What we do *not* claim is a tabletop test of POS-4 alone — and we say so rather than pretend each clause has its own experiment.

N The "constitution" framing and the descent claim

Objection 39 (O-Constitution-39) (the philosopher of science)

"'Constitution' is a political metaphor — a social contract, amendable by vote. Physical law is not legislated. Isn't the framing rhetorical inflation?"

Response. The metaphor is used for one precise feature and the paper is explicit about its limits (§1.4): like a legal constitution, the document states a small set of foundational rules *in writing*, against which all subsequent claims are audited — as opposed to the unwritten "craft tradition" that has governed admissibility in physics for a century. It is emphatically *not* claimed that the rules are chosen by agreement or amendable by preference; their warrant is empirical, and they stand or fall on their consequences (§27). The borrowed feature is auditability, not legislation. If the word's political connotations mislead, the substance is unchanged: a short, written, checkable rule-set with a forwarding pointer to where each consequence is proved. We use "constitution" for the writing-it-down gesture, and disclaim the social-contract reading.

Objection 40 (O-Constitution-40) (the skeptic)

"You claim the eleven clauses *force* the 6D bulk, the anomaly identity, and the boundary law. But those forcings are proved in companion papers, not here. So A1 asserts what it does not demonstrate."

Response. Correct, and the paper states this as a deliberate division of labor rather than a hidden gap (§27, §27.10): A1's job is to state the eleven clauses, name the eleven Principal Theorems, and forward each proof to the companion where it lives — the 6D bulk to Arisaka (2026, A2-GG6), the anomaly identity to Arisaka (2026, A3-BI6), the boundary law to Arisaka (2026, A5-GDOS). An axiomatic document that included its own proofs would be too long to audit at the constitutional layer. So A1 does not *demonstrate* the forcings; it *claims* them and says exactly where each is demonstrated, publishing the cohort simultaneously so the proof is one citation away (§27.11). A serious objection to a forcing is therefore an objection to a specific companion theorem, which the reader can locate and check — not an unsupported assertion.

Objection 41 (O-Constitution-41) (the mathematician)

"Is the descent *unique*? Could a different geometry or theory also satisfy all eleven clauses? If so, the constitution under-determines physics."

Response. Uniqueness is the central structural claim, stated once in §28 and proved in the companions: Arisaka (2026, A2-GG6) establishes the six-dimensional bulk as the unique anomaly-free, moduli-free solution of the axioms, and MSMF (AX-4) is precisely the clause that removes the residual freedom a weaker rule-set would leave. So the constitution is *claimed* not to under-determine physics, with the uniqueness theorem forwarded rather than re-proved here. The honest scope: uniqueness is established within the stated mathematical arena (§4.1); it is not a metamathematical proof that no conceivable structure outside that arena could mimic the clauses. If a genuinely distinct solution satisfying all eleven clauses were exhibited, that would falsify the uniqueness claim — which is exactly the kind of sharp, checkable target an axiomatic program should offer.

Objection 42 (O-Constitution-42) (the logician)

"An axiom system rich enough to 'force all of physics' risks Gödelian incompleteness or outright inconsistency. Have you checked the eleven clauses are even mutually consistent?"

Response. Mutual consistency is demonstrated by *exhibition*, which is the standard route for a physical axiom system: the companion papers construct an explicit model — the 6D bulk with its anomaly-free BI-6 identity and GDOS boundary law — that satisfies all eleven clauses simultaneously (Arisaka, 2026, A2-GG6; Arisaka, 2026, A3-BI6), so the set has a model and is therefore consistent. On Gödel: the constitution is not a formal system aspiring to prove all arithmetic truths; it is a finite filter on physical theories, so Gödelian incompleteness of arithmetic does not bear on it (§1.4). What the clauses "force" is a specific geometry and its low-energy content, not a complete decidable theory of everything. The relevant consistency question — can all eleven hold at once? — is answered yes by the existence of the model, and any failure to construct that model would have falsified the program.

Objection 43 (O-Constitution-43) (the auditor)

"If a companion-paper prediction fails, do you revise an axiom or the companion paper? Without an answer, the constitution is unfalsifiable — failure is always someone else's fault."

Response. The answer is fixed in advance by the descent structure, which is what makes the framework falsifiable rather than evasive (§38, §28): because each prediction is forwarded to a named theorem that follows from named clauses, a failed prediction propagates *upward* to the specific clause or proof it depends on. A failed 3.85 TeV resonance (Arisaka, 2026, P1-KK) or a kaxion absent near 1.95 GHz (Arisaka, 2026, C1-Kaxion) does not leave a free parameter to retune — MSMF forbids that — so it impugns the scale/integer structure that the axioms force, not a dispensable modeling choice. The coherence map (§27.10) makes the dependency explicit precisely so that blame cannot be shifted: each prediction names its upstream clauses. "Someone else's fault" is impossible when the chain is published and one-directional; a break anywhere is a break in the constitution.

Objection 44 (O-Constitution-44) (the historian of science)

"The 'geometrization ladder' from Einstein to GG-Theory is a teleological narrative — Whig history dressed as inevitability."

Response. The risk is real and the ladder is offered as a falsifiable reading, not a teleology (§1.7): the claim is the checkable pattern that each major step absorbed an empirical constant or symmetry into geometry at the cost of added structure — c into Minkowski spacetime, G_N into curvature, gauge fields into bundles — and that the constitution proposes the next rung. It is not claimed that Einstein or Weyl foresaw GG-Theory; the pattern is read off the primary record and would fail if the historical absorptions had gone otherwise. The constitution is presented explicitly as a *proposal* for the next rung, to be vindicated or refuted by experiment (§36.4), not as the inevitable terminus of history. We invite the reader to judge whether the ladder is forced or merely suggestive — the same standard the physics is held to.

O The constitutional tower: classifying twentieth-century physics

Objection 45 (O-Constitution-45) (the skeptic)

"Placing GR, QM, string theory, AdS/CFT, the SM, and ΛCDM in a 'constitutional tower by axiom subset' is post-hoc taxonomy. Any framework could retro-classify

rivals by which of its axioms they use."

Response. The taxonomy earns its keep by doing *quantitative* work, not by re-labeling (§33): each axiom subset is tied to a count — admissible vacua and free continuous parameters — so the classification *predicts*, for instance, why the string cell carries a vast vacuum landscape and the full-axiom cell does not. A purely post-hoc taxonomy cannot produce those numbers from the cell alone. The tower is walked stratum by stratum with each assignment argued individually (§31, §32), not asserted in bulk. The honest limit, stated in §34: the classification is only as objective as the clause definitions, and assigning a framework to a cell is a modeling judgment a critic can dispute case by case — which is why each is defended, not decreed.

Objection 46 (O-Constitution-46) (the string theorist)

"You assign string theory to a specific axiom-subset cell. String theorists would dispute that cell. By what *objective* criterion is a framework placed?"

Response. The criterion is which clauses a framework *implicitly* satisfies versus leaves open, applied uniformly and argued per framework (§31, §32): string theory is placed where it instantiates AX-1–AX-2 (it geometrizes gauge structure and uses the anomaly-inflow machinery) but does not adopt AX-4 in the MSMF sense, which is why it retains a moduli landscape rather than a unique vacuum. That is not an external verdict imposed on the string community; it uses the landscape's *own* count of vacua as the diagnostic (§33). A string theorist who disputes the cell is welcome to point to the clause they believe string theory does satisfy and the construction does not — which is a concrete, resolvable disagreement, not a matter of taste. The classification is built to be argued, and the criterion is on the page.

Objection 47 (O-Constitution-47) (the philosopher)

"The 'vacuum count per axiom subset' presupposes your notion of vacuum and admissibility. You defined the scoreboard — the comparison is rigged."

Response. The scoreboard is defined once, in advance, and stated so it can be contested (§33, §1.5); the guard against rigging is that each cell's count uses that framework's *own* vacuum notion — the string cell's landscape number is the string literature's own, not an externally imposed one, and the full-axiom cell's uniqueness is the OGN-5 integer-ledger result of Arisaka (2026, A3-BI6). So the comparison is not "our metric flatters us"; it is "each framework, counted by its own admissibility, lands in a different cell." The residual subjectivity — which cell a framework belongs to — is conceded openly (§34); the counts *within* a cell are not free. A rigged scoreboard would let the author tune the numbers; here the numbers are inherited from each framework's own practice.

Objection 48 (O-Constitution-48) (the working physicist)

"What does the constitutional classification let me *do* that I could not before? Is it a research tool or a retrospective filing system?"

Response. It is meant as a research tool, and the paper says what it buys (§34): the tower tells you, for a given open problem, which axiom a candidate resolution must *add* — e.g. a measurement-problem proposal that does not adopt AX-3 (OGGEP) is, by the classification, missing the clause that supplies a boundary law, so its incompleteness is predicted, not discovered by trial. It also locates where a new result must sit and which companion theorem it would touch (§27.10). The honest answer to "can I compute something new with it today?" is that the classification is a navigational and diagnostic instrument, not a calculational one; the calculational payoff lives in the companion papers it points to. As a filing system it would be inert; as a map of which axiom each gap needs, it is directional.

Objection 49 (O-Constitution-49) (the Hilbert scholar)

"Hilbert's sixth problem asked to axiomatize physics a century ago and is generally judged to have failed. How is this constitution different from — or better than — that program?"

Response. The comparison with historical axiom systems is drawn directly (§36.3). Hilbert's program sought to axiomatize *specific* theories (mechanics, probability) from within, and stalled where the physics itself was unsettled. The constitution does something narrower and later: it does not axiomatize a finished theory but states admissibility rules that *select* a theory, and it is offered at a moment when the candidate geometry and its consequences can be written down and forwarded for proof (§27). It is "better" only in the testable sense that it commits to sharp, falsifiable downstream predictions rather than to a formalization program. Whether it succeeds where Hilbert's stalled is an empirical question (§36.4); the paper claims the *form* Hilbert sought — a written rule-set — with the added discipline that every clause forwards to a checkable consequence.

Objection 50 (O-Constitution-50) (the QM-reconstruction theorist)

"Hardy (2001), Chiribella–D'Ariano–Perinotti, and Masanes–Müller already reconstruct quantum mechanics from operational axioms. Why a new constitution instead of building on those?"

Response. Those reconstructions are acknowledged as the right kind of work and are not duplicated (§36.3); the difference in scope is the point. The operational reconstructions axiomatize *quantum theory alone* — they recover Hilbert space and the Born rule from information-theoretic principles, but say nothing about gravity, gauge structure, or the Standard-Model parameters. The constitution's claim is that *one* rule-set forces quantum mechanics, general relativity, gauge field theory, and the cosmological inventory together, with the QM sector recovered as the AX-3 (OGGEP) boundary law (Arisaka, 2026, A5-GDOS; Arisaka, 2026, A8-QM). So the relationship is not rivalry but containment: the operational QM axioms correspond, in the tower, to the cell that adopts the openness/measurement clause without the geometry–gauge ones. Building "on" them would still leave gravity and the gauge sector unaxiomatized, which is exactly the gap the constitution exists to close.

P The meta-status: falsifiability, brevity, and arrival

Objection 51 (O-Constitution-51) (the Popperian)

"A framework that reproduces all of established physics as theorems risks being unfalsifiable — it predicts exactly what we already see. What does the constitution itself *forbid*?"

Response. The reproduction of known physics is the consistency requirement; the falsifiable content is what the *shared* clauses forbid (§38). Because measurement, gravity, and the gauge sector descend from one rule-set with no free dimensionless parameter (MSMF), they are not independently adjustable: the constitution forbids, for example, a Standard Model whose anomaly structure escapes the BI-6 lock, a cosmic inventory off the π-locked partition (Arisaka, 2026, A10-Cosmos), and a measurement rule that is not completely positive. Each forbidden possibility is a way the world could be that the constitution says it is not — and several are being tested (the KK resonance (Arisaka, 2026, P1-KK), proton stability). A framework that forbids nothing would indeed be empty; this one forbids the moduli landscape, the tunable coupling, and the decoupled sector, and stakes itself on their absence.

Objection 52 (O-Constitution-52) (the senior community member)

"Twenty-one single-author papers posted at once, with no prior peer review — how should the community weight a constitution that arrives all together?"

Response. By its theorems and its falsifiers, not its mode of arrival — and the simultaneity is a deliberate feature that aids, rather than impedes, scrutiny (§27.11, §27.10): because every claim in A1 forwards to a companion proof, the companion papers are posted together so that each proof is one citation away rather than a promise. One paper of the twenty-two is deliberately not in that set. The capstone GG-A11-Origin, whose upper layers are not yet at the standard the rest of the cohort holds itself to, is in preparation; we name it here rather than quietly omit it, and no claim in this paper and no row of Table 7 depends on it. The framework is built to be audited incrementally — a reader follows the forward-implication chain relevant to their objection without accepting the whole — and to be killed cleanly, since one failed point prediction breaks the shared ledger. Peer review is complemented, not bypassed: the Q&A names the strongest objections, the coherence map exposes every dependency, and the predictions invite refutation. The unusual packaging is a response to the unusual claim (that the pieces are one structure); the evidentiary standard is the ordinary one.

Objection 53 (O-Constitution-53) (the general reader)

"In one sentence: what is the single new, checkable claim of *A1 itself* — not its companions — that could not have been written before this paper?"

Response. In one sentence: that the admissibility of a physical theory can be reduced to a written set of four axioms and seven postulates which together *select* a unique geometry, and that the major frameworks of twentieth-century physics occupy definite, countable cells of the tower built from subsets of those clauses (§28, §29). Everything A1 forwards — the bulk, the anomaly identity, the boundary law — is proved elsewhere; A1's own irreducible contribution is the *constitutional reduction itself* and the classification it makes possible (§32). That claim is checkable in two ways: exhibit a framework that cannot be placed in the tower, or exhibit a distinct geometry satisfying all eleven clauses, and the central claim fails. The new content is the rule-set-plus-classification, not any single re-derived equation.

Objection 54 (O-Constitution-54) (the skeptic)

"The constitution 'fits on one page.' Is that brevity a virtue, or a sign that all the hard content has simply been offloaded to the companion papers?"

Response. Both, and deliberately so (§1.4, §27). The brevity is a virtue for the same reason a legal constitution is short: a rule-set long enough to contain its own proofs is too long to audit *as* a rule-set. And yes, the hard derivations are offloaded — explicitly, with a forwarding pointer to each (§27.10) — because the constitutional layer's job is to state the rules cleanly, not to carry the technical weight. The honest reading the objection presses is correct: A1 alone is not a substitute for the cohort, and we say so (§27.11). The one-page rule-set is the *interface*; the companions are the implementation. A constitution is judged by whether the interface is clean and the implementation is reachable, and both are designed to be exactly that.

Closing remark on the objections. After all, an honest framework should know which questions a working physicist is most likely to raise on first reading, and should answer those questions before they become obstacles to engagement. Fifty-four such questions are answered above, in eleven sections grouped by the community that raises them: the six first-pass readings, the six on the cohort architecture and the placement of string theory, the two on methodology and the integer ledger, the twelve on phenomenology, cosmology and cross-domain reach, and the twenty-eight that press hardest on the foundations themselves — the independence of the axioms, the axiom/postulate split, the "constitution" framing, the classification of twentieth-century physics, and the meta-status of a framework that reproduces known physics as theorems. They are preceded by twenty-five questions of a different kind, in §E, asked in plain language and answered without formalism.

Eighteen of the fifty-four concede something: a structural sharpening the audit surfaced, a philosophical limitation the framework must carry, or a debt to earlier work that the constitutional reading does not discharge. Those concessions are the part of this Part we would ask a hostile reader to weigh first, because a rule-set that never loses an argument has not been tested. The remainder are answered within the constitutional reading itself, each with a forward pointer to the cohort proof location where the technical content sits.

The cohort architecture is, we hope, now visible: GG-A1-Constitution is the rulebook; GG-A2-GG6 and GG-A3-BI6 prove the bulk theorems and the anomaly proof; GG-A5-GDOS and GG-A8-QM prove the boundary law and the textbook QM reformulation; GG-A9-SM, GG-A10-Cosmos and GG-A11-Origin prove the Standard Model parameter collapse, the cosmological partitions, and the closing GRIP cascade. Every objection above traces to a specific cohort proof location, and the cohort papers are released on the same day so that the proof is one click from the objection.

We invite the reader who has finished the present Part to choose, based on the objection that most concerns them, the minimum critical-reading combination of §27.11 and begin there. A first-pass evaluator who completes the relevant two- or three-paper read will be substantially better positioned than one who has read only GG-A1-Constitution, and we hold ourselves to the discipline of naming, for every claim in the constitution, exactly where the proof lives. After all, the strength of a constitution is measured not by what it claims but by how cleanly it can be audited against the technical work that supports it; the cohort architecture is our commitment to that audit.

Part X
References

Cited works, each with a relevance note linking it to the present paper

Unlike a conventional reference list, every entry below carries a short *Relevance* note: a sentence or two saying what the cited work contributes and where in the present paper it bears. The aim is to turn the bibliography from a bare list of sources into a navigable companion — a reader can move through the references and see, at a glance, which axiom, postulate, theorem, or section each one underwrites.

The notes are written for two readers at once. For the newcomer, they trace the intellectual lineage of the constitution: from the foundational work on gauge theory, general relativity, the chiral anomaly, and the renormalization group, through to the twenty-two-paper GG-Theory cohort that the present document compiles. For the specialist, they make the paper's debts explicit and checkable — each note names the specific result it supports, so that no citation is merely decorative.

The references are organized in two groups — first the author's twenty-one companion GG-Theory papers and the Foundation Book (Section A below), then all other works (Section B), each in alphabetical order by first author. The cohort papers (GG-A1-Constitution–GG-A11-Origin, with the C- and P-series) are cited under the canonical keys fixed by the cross-paper coherence map of Part IV.

A. Papers by Katsushi Arisaka (the GG-Theory cohort)

Arisaka, K. (2026). *The Standard Cosmology as Theorem of GG-Theory: The Cosmic Inventory as Observations of One Six-Dimensional Geometry.* Arisaka-GG-A10-Cosmos preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper derives the cosmological parameters $\Omega_m = 1/\pi$, $\Omega_\Lambda = 1 - 1/\pi$, $\Omega_b = 1/(2\pi^2)$, $\Omega_{\rm DM} = 1/\pi - 1/(2\pi^2)$ from the GG-Constitution and the 6D bulk. We cite it whenever the constitution's cosmological-prediction column is invoked. First cited in §1.

Arisaka, K. (2026). *The Geometric Inevitability of Cosmos, Life, and Mind: The Self-Referential Closure of the GG-Theory Program.* Arisaka-GG-A11-Origin.
In preparation. To be posted at https://arisaka-gg.org/ on completion; no result of the present paper depends on it.
Relevance. The closing capstone of the eleven-paper A-series. Operationalizes the GRIP cascade through layered identity-formation (Part V), states the T-Origin theorem, and develops the universal-identity insight in which the OGN-5 ledger threads through atoms, molecules, ATP, DNA, and the first cell. We cite it where the constitutional cascade is followed to its operational

anatomy and where the universal-identity insight closes a chain of reasoning that began with AX-2 and AX-4. First cited in §3.1.

Arisaka, K. (2026). *GG-Theory with GG-6: Geometry–Gauge Locking at the 6D Bulk (GG-6) at the Heart of Grand Geometric Theory (GG-Theory).* Arisaka-GG-A2-GG6 preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper develops the concrete six-dimensional geometric stage suggested by the axioms (especially GGEP and anomaly inflow requirements). In the present foundational paper we cite it whenever the 6D bulk, the four-component BI-6 anomaly polynomial, the OGN-5 integer ledger, or the $\mathrm{Spin}(1,5) \times \mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$ composite gauge group is invoked. First cited in §1.

Arisaka, K. (2026). *Anomaly Freedom of BI-6: The Modified Bianchi Identity (BI-6) for the Six-Force, Six-Dimensional Bulk (GG-6).* Arisaka-GG-A3-BI6 preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper supplies the rigorous Hopkins-Singer differential-cohomology proof that the four-component anomaly polynomial $X_4 = \mathrm{tr}(R \wedge R) - \mathrm{tr}(F_{\mathrm{SU}(5)} \wedge F_{\mathrm{SU}(5)}) - \frac{2}{5} F_B \wedge F_B - \frac{2}{5} F_{Qi} \wedge F_{Qi}$ is exact, establishing $|a/c| = |a/d| = 5/2$ as the geometry-gauge trace-ratio lock that POS-AF demands. First cited in §1.

Arisaka, K. (2026). *From Euclid to GG-6: The Realization of Euclid's Elements in Six Dimensions — GU-5, OGN-5, and a Parameter-Free Reconstruction of Modern Physics.* Arisaka-GG-A4-Euclid.
Preprint, available at https://arisaka-gg.org/.
Relevance. The historical companion to the GG6 Trio. Pedagogical commentary on the long chain from Euclid through Newton, Riemann, Maxwell, and Einstein to the GG-6 stage. We cite this paper whenever the historical positioning of the 6D bulk against its predecessors is invoked. First cited in §3.1.

Arisaka, K. (2026). *GDOS: Geometric Dynamics of Open Systems — 6D GG-6 Bulk Projected to 4D Boundary for Quantum Measurement, General Relativity, and QFT.* Arisaka-GG-A5-GDOS.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper develops the open-system "runtime" implied by OGGEP and the postulates (positivity, RG-compatibility, falsifiability). We cite it whenever the boundary law $\mathcal{L}_{\mathsf{GDOS}}$, the Hilbert-space embedding, the Born rule, the Schrödinger limit, the modified TOV equation, or the BRST/Slavnov-Taylor identities are invoked, since their proofs live there as the eleven GDOS Principal Theorems T1–T11. First cited in §1.

Arisaka, K. (2026). *The GRIP on GDOS — GRIP: the Geometric Engine of Symmetry Breaking, from the Big Bang to Mind.* Arisaka-GG-A6-GRIP preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper formalizes the four Geometric-Invariance pillars descending from OGGEP: the Total Geometric-Gauge object TGG, the Covariant Conservation Identity CCI, the Geometric Free-Energy Functional GFF, and the Gauge-Runtime Invariance Pipeline GRIP

(DGI → GSSB → GA). We cite it when the geometric-side consequences of the GG-Constitution are invoked. First cited in §1.

Arisaka, K. (2026). *The Qi-4 Pillars — Qi-QUA, Qi-EP, Qi-CON, Qi-HAL: The Quantum-Information Backbone of GDOS*. Arisaka-GG-A7-Qi4 preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper formalizes the four Quantum-Information pillars descending from OGGEP: Qi-QUA (qua-state preparation), Qi-EP (quantum equivalence principle), Qi-CON (decoherence/contraction), and Qi-HAL (holographic alphabet). We cite it when the quantum-information-side consequences of the GG-Constitution are invoked. First cited in §1.

Arisaka, K. (2026). *Quantum Mechanics Derived from GG-Theory as Projection from 6D Bulk to 4D Boundary*. Arisaka-GG-A8-QM.
Preprint, available at https://arisaka-gg.org/.
Relevance. The first paper of the 4D-Physics Trio. Operationalizes T2 Operational Closure and T7 4D Quantum Mechanics from GDOS into a concept-by-concept reformulation of textbook quantum mechanics: the Born rule as a theorem of the Stinespring dilation, EPR / Bell / CHSH / Aspect / Hensen / Giustina as evidence of the non-invertibility of the 6D-to-4D projection, Schrödinger's cat as a GDOS boundary-decoherence statement, and the central thesis that Einstein was right in 6D and Bohr was right in 4D, both within their respective domains. First cited in §1.7.

Arisaka, K. (2026). *The Standard Model as Theorem of GG-Theory: Its 28 Parameters as Observations of One Six-Dimensional Geometry*. Arisaka-GG-A9-SM preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. This companion paper derives the Standard Model parameters (gauge couplings, Yukawa couplings, CKM/PMNS angles, EW vacuum expectation value $v \approx 246\,\mathrm{GeV}$, the cosmological-constant scale $m_\Lambda \approx 6\,\mathrm{meV}$, and the lock-mass cluster near $M_{\mathrm{lock}} \approx 3.85\,\mathrm{TeV}$) from the 6D bulk and the OGN-5 ledger. We cite it whenever the constitution's empirical-prediction column is invoked. First cited in §1.

Arisaka, K. (2026). *GG-Theory Foundation Book: Constitution, GG-6 Trio, GDOS Trio, and 4D-Physics Trio Compiled into a Single Reference*. Arisaka-GG-BookI (in preparation).
Preprint, available at https://arisaka-gg.org/.
Relevance. The Foundation Book compiles the constitution and its descent chain into a single accessible reference. We cite it where a one-volume overview is more useful than the individual preprints, and where cross-domain implications (life science, neuroscience, complex systems) of the GG-Constitution are sketched. First cited in §36.4.

Arisaka, K. (2026). *The Kaxion: Cold Dark Matter as the Non-Spatial Compact-Angle Pseudoscalar of GG-6*. Arisaka-GG-C1-Kaxion preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The cosmology phenomenology companion to GG-A10-Cosmos. The kaxion field of mass set by the 6D-bulk lock-length integer $K = 35$ produces a dark-matter oscillation at fractional

frequency $\Delta\nu/\nu = 1/35$ in the μeV range; explicit haloscope and microwave-cavity falsifiers. Any verified discovery at $\Delta\nu/\nu \neq 1/35$ falsifies the OGN-5 ledger and so the constitutional clauses AX-4 MSMF and POS-6 OGN upstream. First cited in §20.

Arisaka, K. (2026). *The Hubble Tension in the Light of GG-Theory: The Hubble Constant as One Reading of a Derived Expansion History $H(t)$*. Arisaka-GG-C2-Hubble preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The second paper of the Cosmology & Astrophysics Branch: reads the persistent discrepancy between early- and late-universe Hubble measurements as the two ends of one geometric corridor of the 6D bulk, rather than as a systematic error or new fluid. Cited in the Part-IV handoff (inventory, relations map, and bridge subsection). First cited in §27.8.

Arisaka, K. (2026). *Black-Hole Entropy under GG-Theory: The GDOS Reading of the Horizon as an OGGEP Port — with the Exact Bekenstein–Hawking $A/4G_N$ Derived from Induced Gravity*. Arisaka-GG-C3-BH preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The third paper of the Cosmology & Astrophysics Branch and the cohort's strong-gravity anchor: the horizon treated as an OGGEP port, with the exact $A/4$ coefficient derived. Cited in the Part-IV handoff (inventory, relations map, and bridge subsection). First cited in §27.8.

Arisaka, K. (2026). *The GG-6 Lock Cluster: A Non-Spatial Kaluza–Klein Resonance near 3.85 TeV as the Standing LHC Falsifier of GG-Theory*. Arisaka-GG-P1-KK preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The first paper of the Predictions Branch. Specific phenomenology of the lock cluster at $M_{\text{lock}} = (1/2)\, M_{\text{Pl}}\, \mathrm{e}^{-35} \approx 3.85\,\text{TeV}$, with explicit LHC and future-collider falsifiers. Any verified collider deviation from the predicted Kaluza-Klein resonance pattern at 5σ falsifies T4 + T6 jointly. First cited in §27.8.

Arisaka, K. (2026). *Why Three Generations: A Three-Leg Derivation of $N_g = 3$ from BI-6, MSMF, and GDOS Morse Stability*. Arisaka-GG-P2-N3 preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The second paper of the Predictions Branch: the family number derived as a squeeze between a CP-violation lower bound and a GDOS Morse/budget upper bound, with the conditioning declared by name. Cited in the Part-IV handoff (inventory, relations map, and bridge subsection). First cited in §27.8.

Arisaka, K. (2026). *The Electron as the Ground State of Nature: The Six Oldest Questions about the Electron, Closed and Fenced within GG-Theory*. Arisaka-GG-P3-Electron preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The third paper of the Predictions Branch: identity, absolute stability, the two excited copies, the positron as conjugate readout, pointlikeness, and field response derived as six faces of ground-state-ness, with every fence declared; imports GG-P2-N3's $N = 3$ verbatim. Cited in the Part-IV handoff (inventory, relations map, and bridge subsection). First cited in §27.8.

Arisaka, K. (2026). *The Real Geometry Beneath the Complex Numbers of Physics: Positive Frequency is Holomorphy — from Cardano's Cubics to Twistor Space, via the Sixth Dimension of GG-Theory*. Arisaka-GG-P4-Real preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The first member of the Foundations Branch: the origin of i. Derives the two complex structures of physics from two real structures of the 6D bulk — the compact phase circle, whose quarter-turn is the unique circle-compatible complex structure on every charged sector (the gauge i, T-P4-1), and the causal clock, whose one-sided spectrum forces the unique positive-energy polar phase (the state-space i, T-P4-2) — with their forced on-shell agreement, the Feynman–Stückelberg pairing, derived as the existence of antiparticles (T-P4-3), and the bridge that positive frequency is holomorphy at the Hardy, forward-tube, and twistor levels (T-P4-6/7). We cite it as the standalone development of the origin of the boundary's complex structure, beside GG-A8-QM's QM-register treatment. First cited in §3.1.

Arisaka, K. (2026). *The Mirrors of Matter: Why Every Particle Has a Twin, Why Nature's Mirrors Break, and Why the Universe Is Made of Matter*. Arisaka-GG-P5-CPT preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The second member of the Foundations Branch: the mirrors and the matter. Derives C, P, and T as the orientation reversals of the three real factors of the 6D bulk — the fiber circle, the spatial slice, and the causal clock — with the unitary/antiunitary table forced rather than assigned (T-P5-1) and the CPT theorem as orientation bookkeeping (T-P5-2); routes the cosmic matter excess through the flavored chain fed by GG-A9-SM's ledger phases and feeding GG-A10-Cosmos's η_B chain, its sign carried by the Majorana parity $\alpha_{31} = \pi$ (derived-conditional on its named finite-temperature hypothesis); and consolidates the four-endowment definition of time. First cited in §3.1.

Arisaka, K. (2026). *The Proton as the Ground Geometric Attractor of Matter: The Eleven Questions of the Proton, Closed and Fenced within GG-Theory*. Arisaka-GG-P6-Proton preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The fourth member of the Predictions Branch, sister to GG-P3-Electron: the proton as the GGA of the baryonic stratum, with baryon number carried as a winding of the compact geometry rather than as a bookkeeping label — written by the same twist that breaks the unified gauge symmetry and splits the Higgs multiplet — so that the decay the grand unified theories insisted on is forbidden by the geometry rather than merely unobserved. Eleven questions closed as faces of one fact, every import at its proved grade and every kill criterion stated; a single verified proton decay falsifies it. First cited in §3.1.

Arisaka, K. (2026). *Symmetry, Conservation, and Geometry: Seven Steps from Noether, Bianchi, to Hopkins–Singer, and the Ledger the Open-System Turn Pays Out*. Arisaka-GG-W1-Symmetry preprint.
Preprint, available at https://arisaka-gg.org/.
Relevance. The first of the two white papers, and the *diachronic* one: it walks the century of symmetry and conservation in the order it was found and shows the conviction that symmetry

causes conservation loosening at seven historical steps, until what remains conserved is an integer with nowhere to move — then places the program at the arc's end, at declared grades, with its payout set beside the measurements. Derives nothing new: every result is carried at its parent's declared grade. First cited in §27.9.

Arisaka, K. (2026). *The Circle That Remembers, the Interval That Forgets: GG-Theory and the Sixteen Problems of Particle Physics and Cosmology.* Arisaka-GG-W2-Holonomy preprint. Preprint, available at https://arisaka-gg.org/.
Relevance. The second of the two white papers, and the *synchronic* one: it takes a single exact statement — a holonomy requires a closed loop and the interval fiber has none, so the circle remembers and the interval forgets — and follows it to sixteen of the questions physics has not closed, closing with the named, dated measurements on which six of the sixteen treatments die outright. Like its sibling it derives nothing new, carrying every result at its parent's declared grade. First cited in §27.9.

B. Other references

Adler, S. L. (1969). Axial-vector vertex in spinor electrodynamics. *Physical Review*, *177*, 2426–2438. https://doi.org/10.1103/PhysRev.177.2426
Relevance. Adler's 1969 calculation of the axial-vector vertex is the foundational discovery that the boundary quantum effective action does not honor the classical chiral Ward identity at one loop. In the constitutional reading of POS-3 AF, the Adler anomaly is not a pathology of the bulk field theory but the AX-3 OGGEP projection shadow of a bulk-side classical-topological identity descended from Bianchi 1902: the boundary's triangle-diagram measurement of its own inability to register the deeper bulk closure. Adler is cited as the historical anchor for that re-reading. First cited in §14.

Aharonov, Y., & Bohm, D. (1959). Significance of electromagnetic potentials in the quantum theory. *Physical Review*, *115*(3), 485–491. https://doi.org/10.1103/PhysRev.115.485
Relevance. The Aharonov–Bohm effect demonstrates that holonomy of a gauge connection is physically observable even when local field strengths vanish. This is a canonical precedent for GGEP's insistence that the invariant content of the composite connection includes global/holonomy data, supporting "quantum phase as geometry." First cited in §6.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. https://doi.org/10.1109/TAC.1974.1100705
Relevance. Akaike's information criterion is a quantitative formulation of the "Occam penalty" in model selection. We cite it as historical background for POS-6 (OGN): in GG-Theory, minimality is enforced not only in model structure but also in normalization conventions to prevent hidden continuous tuning. First cited in §8.

Almheiri, A., Engelhardt, N., Marolf, D., and Maxfield, H. (2020). The entropy of bulk quantum fields and the entanglement wedge of an evaporating black hole. *Journal of High Energy Physics*, *2019*(12), 63. https://doi.org/10.1007/JHEP12(2019)063

Relevance. The Almheiri–Engelhardt–Marolf–Maxfield and Penington–Shenker–Stanford–Yang papers of 2019–2020 (the "islands formula") showed that the Page curve of black-hole evaporation can be recovered from semiclassical computations by including "island" regions in the entanglement wedge. In the AX-3 lineage, the islands formula is the first construction in which the operational projection $\mathcal{D}$ necessarily includes non-local bulk regions to honor boundary unitarity — a direct quantum-information confirmation that OGGEP is the right operational reading of the holographic principle. First cited in §7.

Alvarez-Gaumé, L., & Witten, E. (1984). Gravitational anomalies. *Nuclear Physics B, 234*(2), 269–330. DOI: 10.1016/0550-3213(84)90066-X.

Relevance. Alvarez-Gaumé and Witten classify gravitational and mixed anomalies across arbitrary dimensions, exposing the algebraic structure (descent equations, characteristic classes) that underlies what the constitutional reading takes to be a single bulk-side classical-topological identity. In the language of POS-3 AF, the gravitational anomaly is the AX-3 OGGEP projection shadow of the bulk diffeomorphism-Bianchi closure on the AX-2 GGEP composite connection. Cited as the canonical technical reference for the descent-class structure that makes the bulk closure $dX_4 = 0$ rigorous in arbitrary dimension. First cited in §16.

Aristotle (c. 350 BCE). *Physics* and *Metaphysics*. Translations as in Barnes (ed.), *The Complete Works of Aristotle*, Princeton University Press, 1984.

Relevance. Aristotle's insistence that knowledge of natural phenomena must be grounded in observation is the philosophical seed of empiricism. In the constitutional reading of POS-7 MF, Aristotle is cited as the deepest historical anchor for the discipline that every theoretical claim must ultimately compile to a registered observation. First cited in §20.

Aspect, A., Dalibard, J., & Roger, G. (1982). Experimental test of Bell's inequalities using time-varying analyzers. *Physical Review Letters*, *49*(25), 1804–1807. https://doi.org/10.1103/PhysRevLett.49.1804

Relevance. The first decisive laboratory verification of CHSH violation under time-varying measurement settings, ruling out local hidden-variable theories with specifiable causal sufficiency. We cite it as the experimental closure of the locality crisis identified by Bell (1964) and re-cite it whenever the axiomatic treatment of openness and operational locality is invoked, especially in the bridge from AX-1 LC to AX-3 OGGEP. First cited in §1.1.

Atiyah, M. F., & Singer, I. M. (1963). The index of elliptic operators on compact manifolds. *Bulletin of the American Mathematical Society*, *69*, 422–433.

Relevance. The original announcement of the Atiyah–Singer index theorem. In the constitutional reading of POS-3 AF, this theorem is the mathematical engine behind anomaly cancellation: the index of a Dirac operator equals a topological integral of characteristic classes, so the boundary anomaly polynomial is locked to bulk topological data. Cited as the historical anchor for the geometric-origin reading of POS-3. First cited in §16.

Atiyah, M. F., & Singer, I. M. (1968). The index of elliptic operators I. *Annals of Mathematics*, *87*, 484–530.

Relevance. The full proof of the Atiyah–Singer index theorem. In the constitutional reading of POS-3 AF, the 1968 paper is the technical foundation on which the modern anomaly-as-index picture rests: every chiral anomaly in physics is a direct corollary of this single mathematical identity. First cited in §16.

Banks, T., & Seiberg, N. (2011). Symmetries and strings in field theory and gravity. *Physical Review D*, *83*, 084019. https://doi.org/10.1103/PhysRevD.83.084019

Relevance. The modern statement that global symmetries must either be gauged or be broken in any consistent theory of quantum gravity. In the constitutional reading of POS-1 GI, this paper supplies the deepest justification for treating gauge invariance as a primary axiomatic filter rather than a derived feature. First cited in §14.

Bardeen, W. A. (1969). Anomalous Ward identities in spinor field theories. *Physical Review*, *184*, 1848–1857.

Relevance. Develops the Ward-identity viewpoint of anomalies and clarifies how anomaly terms appear in current conservation laws. POS-3 treats such symmetry violations as fatal unless canceled by inflow; Bardeen's analysis is a canonical reference for this "symmetry grammar" perspective. First cited in §16.

Batalin, I. A., & Vilkovisky, G. A. (1981). Gauge algebra and quantization. *Physics Letters B*, *102*, 27–31.

Relevance. The BV (Batalin–Vilkovisky) formalism generalizes BRST quantization to open and reducible gauge algebras. In the constitutional reading of POS-1 GI, BV is the mathematical apparatus that makes the dynamical-gauge-invariance (DGI) layer well-defined for the full ladder of gauge structures used by GG-Theory. First cited in §14.

Bayes, T. (1763). An essay towards solving a problem in the doctrine of chances. *Philosophical Transactions of the Royal Society of London*, *53*, 370–418 (posthumous; communicated by R. Price).

Relevance. Bayes' theorem: the prototype of every subsequent inverse-probability statement. In the constitutional reading of POS-4 CP, Bayes is cited as the historical anchor for treating probability as a registered quantity in physics, the foundation on which Kolmogorov's later axiomatization is built. First cited in §17.

Bekenstein, J. D. (1973). Black holes and entropy. *Physical Review D*, *7*(8), 2333–2346.

Relevance. We cite Bekenstein as the original statement that black holes carry entropy proportional to horizon area. In the GG-Theory viewpoint, black-hole thermodynamics is a paradigmatic open-system ledger problem: the boundary/horizon acts as a "port" and the correct scalar accounting principle anticipates the GFF idea used in GDOS. First cited in §7.

Bell, J. S. (1964). On the Einstein Podolsky Rosen paradox. *Physics*, *1*, 195–200.

Relevance. Bell's theorem clarifies that the measurement problem is not merely philosophical: operational predictions about correlations constrain the kinds of "hidden variable" completions that remain possible. This motivates treating measurement as an axiomatic issue rather than an interpretational afterthought. First cited in §1.1.

Bell, J. S. (2004). *Speakable and Unspeakable in Quantum Mechanics* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511815676
Relevance. Bell's collected papers contain the sharpest discussions of "local causality" in the foundations of quantum theory. We cite this as historical context for AX-1: GG-Theory adopts "local causality" as a constitution-level constraint on operational predictions (records must be retarded and non-signaling), not as an interpretational afterthought. First cited in §7.

Bell, J. S. & Jackiw, R. (1969). A PCAC puzzle: $\pi^0 \to \gamma\gamma$ in the σ-model. *Il Nuovo Cimento A* **60**, 47–61. doi:10.1007/BF02823296.
Relevance. The Bell–Jackiw companion to Adler 1969, resolving the $\pi^0 \to \gamma\gamma$ puzzle in the σ-model by way of the same axial anomaly. In the constitutional reading, the Bell–Jackiw calculation co-discovered (with Adler) that the boundary quantum loop registers an obstruction whose origin sits one dimension upstream: the boundary 4D effective action is the AX-3 OGGEP projection of a bulk-side classical Bianchi identity descended from Bianchi 1902. Cited as the second historical anchor for POS-3 AF's boundary-shadow-of-bulk-identity framing. First cited in §14.

Bernoulli, J. (1713). *Ars Conjectandi*. Basel: Thurnisii (posthumous).
Relevance. The law of large numbers. In the constitutional reading of POS-4 CP, Bernoulli's *Ars Conjectandi* is the deepest historical anchor for treating frequencies of observation as a legitimate physical quantity, justifying the move from idealized probabilities to operationally-registered statistics. First cited in §17.

Berry, M. V. (1984). Quantal phase factors accompanying adiabatic changes. *Proceedings of the Royal Society A*, *392*(1802), 45–57. https://doi.org/10.1098/rspa.1984.0023
Relevance. Berry's phase is a canonical example of "quantum from geometry": measurable phases arise from holonomy in parameter space. It provides historical and technical support for AX-2's emphasis that quantum structure can be encoded geometrically in connections and their holonomies rather than imposed by quantization rules. First cited in §6.

Bertlmann, R. A. (1996). *Anomalies in Quantum Field Theory*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198507628.001.0001
Relevance. This monograph provides the standard mathematical treatment of anomaly polynomials and descent. It supports the formal statements in POS-3, where we package anomalies into differential-form data suitable for bulk–boundary cancellation. First cited in §16.

Bethe, H. A. (1947). The electromagnetic shift of energy levels. *Physical Review*, *72*(4), 339–341. https://doi.org/10.1103/PhysRev.72.339
Relevance. Bethe's non-relativistic calculation of the Lamb shift, the empirical turning point that demonstrated renormalization as a systematic physical procedure rather than an *ad hoc* subtraction. In the constitutional reading of POS-5 RG, Bethe 1947 is cited as the operational starting point of the renormalization program. First cited in §18.

Bianchi, L. (1902). Sui simboli a quattro indici e sulla curvatura di Riemann. *Rendiconti della R. Accademia dei Lincei*, *11*, 3–7.

Relevance. Luigi Bianchi's 1902 identity for the Riemann curvature tensor is the historical ancestor of the entire constitutional reading of POS-3 AF. In modern notation $\nabla_{[\mu}R_{\nu\rho]\sigma\tau} = 0$, equivalently $dR = 0$ on the Levi-Civita connection; together with the abelian Bianchi identity $dF = 0$ inherent in Maxwell, it is the geometric ancestor of BI-6 and of every bulk-side classical-topological identity that the cohort framework rests on. In the present reading the boundary 4D "anomaly" of the standard textbook is the AX-3 OGGEP projection shadow of this Bianchi-descended bulk closure; the Green–Schwarz construction is its B_2-coupled rewrite; the Hopkins–Singer differential-cohomology proof is its precise differential-character statement. Cited as the founding source for the bulk-side classical reading of anomaly freedom. First cited in §6.

Bohr, N. (1928). The quantum postulate and the recent development of atomic theory. *Nature*, *121*, 580–590. (Earlier in: *Atti del Congresso Internazionale dei Fisici*, Como, 1927.)

Relevance. Bohr's 1928 Como/Solvay address introduced the complementarity principle: a quantum measurement necessarily involves an apparatus described classically, and the complementary aspects of a quantum object (position vs. momentum, wave vs. particle) cannot be jointly registered. In the AX-3 lineage, Bohr's principle is the first foundational statement that the bulk-side quantum description and the boundary-side operational record are not the same object — a structural fact that AX-3 OGGEP takes as a primitive of the constitution rather than an interpretational stance. First cited in §7.

Bombelli, L., Lee, J., Meyer, D., and Sorkin, R. D. (1987). Space-time as a causal set. *Physical Review Letters*, *59*(5), 521–524. https://doi.org/10.1103/PhysRevLett.59.521

Relevance. The causal-set approach takes Minkowski's identification of causal ordering with the geometric structure of spacetime to its discrete limit: spacetime *is* a partially ordered set whose order relation *is* the causal structure. In the AX-1 lineage, this is the most aggressive realization of the constitutional thesis that causality is a primitive of the bulk geometry rather than a derived feature of the dynamics; we credit it as one of the lines of work to which AX-1 LC owes its operational reading. First cited in §5.

Born, M. (1926). Zur Quantenmechanik der Stoßvorgänge. *Zeitschrift für Physik*, *37*, 863–867. https://doi.org/10.1007/BF01397477

Relevance. Born's probabilistic interpretation underlies the Born rule, which is central to the modern measurement postulate in quantum mechanics. It is cited here to emphasize that probability entered QM as a foundational rule rather than as a derived dynamical theorem, motivating the GG-Theory demand that measurement semantics be axiomatic rather than ad hoc. First cited in §1.1.

Born, M., & Wolf, E. (1999). *Principles of Optics* (7th ed.). Cambridge University Press.

Relevance. A standard reference for geometric optics, wave propagation, and the eikonal approximation. It supports the UEP dictionary used in this paper: "least time" emerges as an operational face of variational principles once one passes to ray/characteristic descriptions and measurement protocols. First cited in §15.

Bousso, R. and Polchinski, J. (2000). Quantization of four-form fluxes and dynamical neutralization of the cosmological constant. *Journal of High Energy Physics*, *2000*(06), 006. https://doi.org/10.1088/1126-6708/2000/06/006

Relevance. Bousso and Polchinski estimated that the discretuum of four-form flux vacua in string theory produces of order 10^{500} admissible solutions, the canonical "string landscape" count. In the AX-4 lineage, this is the quantitative diagnosis of what GGEP-closed looks like without AX-4 MSMF: a vacuum count so vast that no first-principles selection is possible. AX-4 MSMF is the constitutional remedy: addition of one axiom collapses the 10^{500} landscape to exactly one admissible bulk. First cited in §8.

Breuer, H.-P., & Petruccione, F. (2002). *The Theory of Open Quantum Systems*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199213900.001.0001

Relevance. This standard reference develops the mathematics of open quantum systems (reduced dynamics, master equations, Markovian limits). It anchors our claim that openness is not optional in realistic modeling, and it provides the mature language (CPTP maps and generators) that the GG-Constitution intends to elevate to first-class status. First cited in §1.3.

Bridgman, P. W. (1927). *The Logic of Modern Physics*. New York: Macmillan.

Relevance. Bridgman's operationalism is an early systematic attempt to define scientific concepts by measurement operations. We cite it as philosophical and methodological background for POS-7 (MF): in GG-Theory, every claim must compile to an explicit instrument protocol and an auditable falsifier. First cited in §20.

Bub, J., & Pitowsky, I. (2010). Two dogmas about quantum mechanics. In S. Saunders, J. Barrett, A. Kent, & D. Wallace (Eds.), *Many Worlds? Everett, Quantum Theory, and Reality* (pp. 433–459). Oxford: Oxford University Press.

Relevance. Bub and Pitowsky's informational-realist axiomatization of quantum mechanics treats quantum theory as a non-classical theory of information, with the Born rule emerging from operational constraints rather than from a hidden ontology. In the constitutional reading of AX-3 OGGEP, Bub-Pitowsky is a structural neighbor: both programs promote operational content to first-class status, and the GG-Theory program inherits the Bub-Pitowsky stance that "measurement" is not in need of metaphysical resolution before it can be made mathematically precise. First cited in §36.2.

Buckingham, E. (1914). On physically similar systems; illustrations of the use of dimensional equations. *Physical Review*, *4*(4), 345–376. https://doi.org/10.1103/PhysRev.4.345

Relevance. The π-theorem: physical laws must be expressible as relations among dimensionless ratios. In the constitutional reading of POS-5 RG, Buckingham is cited as the pre-history of the modern renormalization-group: scale invariance is not a special property of fixed points, it is the default form of every physical law. First cited in §18.

Busch, P., Lahti, P. J., & Mittelstaedt, P. (1996). *The Quantum Theory of Measurement* (2nd rev. ed.). Berlin: Springer.

Relevance. Provides a comprehensive modern treatment of POVMs, instruments, and measurement models beyond ideal projective measurements. This is directly used in POS-7 to formalize "measurement" as a lawful operational map rather than a vague collapse postulate. First cited in §20.

Caldeira, A. O., & Leggett, A. J. (1983). Path integral approach to quantum Brownian motion. *Physica A, 121*(3), 587–616.
Relevance. A classic application of influence-functional methods yielding dissipative and decohering dynamics. It is cited as historical/technical background for why open-system dynamics is unavoidable in realistic measurement, motivating AX-3's axiomatic treatment of open evolution. First cited in §7.

Callan, C. G. (1970). Broken scale invariance in scalar field theory. *Physical Review D, 2*(8), 1541–1547. DOI: 10.1103/PhysRevD.2.1541.
Relevance. One of the original papers formulating the Callan–Symanzik equation and the modern view of renormalization-group flow as a differential statement of scale dependence. It provides historical grounding for POS-5: "scale covariance" is not optional if the theory aims to be resolution-independent. First cited in §18.

Callan, C. G., Jr., & Harvey, J. A. (1985). Anomalies and fermion zero modes on strings and domain walls. *Nuclear Physics B, 250*(1–4), 427–436. DOI: 10.1016/0550-3213(85)90489-4.
Relevance. A classic source on anomaly inflow: boundary anomalies are canceled by bulk topological currents. It supports POS-3 by exemplifying how "inflow" restores gauge consistency and motivates treating cancellability by inflow as an admissibility rule rather than a model-dependent trick. First cited in §16.

Chern, S.-S. (1946). Characteristic classes of Hermitian manifolds. *Annals of Mathematics*, *47*, 85–121.
Relevance. The Chern–Weil construction: characteristic classes as integer invariants of a fiber bundle's curvature. In the constitutional reading of POS-6 OGN, Chern–Weil supplies the modern mathematical justification for the discipline that gauge-bundle data must be specified by integers, not by continuous fitted parameters. First cited in §16.

Chern, S.-S., & Simons, J. (1974). Characteristic forms and geometric invariants. *Annals of Mathematics*, *99*, 48–69.
Relevance. The Chern–Simons three-form: the local primitive whose exterior derivative is the anomaly polynomial. In the constitutional reading of POS-3 AF, Chern–Simons is the geometric object that makes inflow cancellation a local, computable identity rather than a formal rewriting. First cited in §16.

Choi, M.-D. (1975). Completely positive linear maps on complex matrices. *Linear Algebra and its Applications*, *10*(3), 285–290. `https://doi.org/10.1016/0024-3795(75)90075-0`
Relevance. Choi's theorem characterizes complete positivity, the mathematical core of physical admissibility for open-system dynamics and measurement instruments. AX-3 and POS-CP rely

on complete positivity as the operational replacement for "no negative probabilities" across all open systems. First cited in §7.

Clauser, J. F., Horne, M. A., Shimony, A., and Holt, R. A. (1969). Proposed experiment to test local hidden-variable theories. *Physical Review Letters*, *23*(15), 880–884. https://doi.org/10.1103/PhysRevLett.23.880
Relevance. The CHSH inequality is the form of Bell's theorem that every subsequent experiment has actually tested, and it is the bound $|S| \leq 2$ that the worked example of AX-1 LC uses to separate the causal-arrow constraint from the factorizability constraint. The constitutional reading turns on exactly that separation: AX-1 forbids signaling, and does not forbid non-classical correlation. First cited in §5.

Connes, A. (1994). *Noncommutative Geometry*. San Diego: Academic Press.
Relevance. Connes' noncommutative-geometry rewriting of gauge theory and the Standard Model. In the constitutional reading of POS-1 GI, this work shows that gauge invariance can be reformulated as a statement about the spectral geometry of the observable algebra rather than about a specific Lagrangian, supporting the algebra-first reading of LGI used by GG-Theory. First cited in §14.

Cover, T. M., & Thomas, J. A. (2006). *Elements of Information Theory* (2nd ed.). Wiley. https://doi.org/10.1002/047174882X
Relevance. Information theory supplies a precise quantitative language for "information" as an operational resource. We cite this text to support the appendix discussion where free-energy-like functionals are related to KL divergence and where MF requires explicit information-theoretic accounting for measurement and compression. First cited in §D.1.

Crooks, G. E. (1999). Entropy production fluctuation theorem and the nonequilibrium work relation for free energy differences. *Physical Review E*, *60*(3), 2721–2726.
Relevance. A cornerstone of stochastic thermodynamics connecting forward/backward path probabilities and nonequilibrium work. We cite it as a modern exemplar of how open-system probability flows carry rigorous, testable constraints—precisely the style enforced by POS-4 and POS-7. First cited in §5.

Daniel, M., & Viallet, C. M. (1980). The geometrical setting of gauge theories of the Yang–Mills type. *Reviews of Modern Physics*, *52*(1), 175–197.
Relevance. A standard review formulating Yang–Mills gauge theories — and the Standard-Model gauge group — as connections on principal fiber bundles. Cited under AX-2 milestone (7) as the mature fiber-bundle formalism that GGEP adopts rather than originates. First cited in §6.

Davies, P. C. W., Fulling, S. A., and Unruh, W. G. (1976). Energy-momentum tensor near an evaporating black hole. *Physical Review D*, *13*(10), 2720–2723. https://doi.org/10.1103/PhysRevD.13.2720
Relevance. Davies, Fulling, and Unruh's 1976 paper established that the vacuum state seen by an inertial observer appears as a thermal bath to a uniformly accelerated observer. In the

AX-3 lineage, the Davies–Fulling–Unruh construction is the canonical demonstration that the operational boundary observer's record depends on the boundary's motion — i.e., on which $\mathcal{D}$ is used — and not only on the bulk state. It is the first quantum-field-theoretic demonstration that OGGEP projections genuinely partition the bulk content into observer-dependent boundary registrations. First cited in §7.

Davies, E. B., & Lewis, J. T. (1970). An operational approach to quantum probability. *Communications in Mathematical Physics*, *17*, 239–260. https://doi.org/10.1007/BF01647093
Relevance. This paper is a foundational source for the instrument/operation viewpoint of measurement. It supports AX-3's claim that "measurement" should be defined by operations (instruments/POVMs) rather than treated as an interpretational postulate separate from dynamics. First cited in §5.

de Haro, S., Skenderis, K., & Solodukhin, S. N. (2001). Holographic reconstruction of spacetime and renormalization in the AdS/CFT correspondence. *Communications in Mathematical Physics*, *217*, 595–622. https://arxiv.org/abs/hep-th/0002230
Relevance. This work systematized holographic renormalization, making precise how bulk radial evolution corresponds to boundary RG flow. We cite it as a technical antecedent for POS-5: RG-compatibility is treated as a structural commutation requirement between coarse-graining and bulk–boundary dictionaries. First cited in §18.

Diophantus of Alexandria (c. 3rd century CE). *Arithmetica*. English translation: T. L. Heath, *Diophantus of Alexandria: A Study in the History of Greek Algebra*, Cambridge University Press, 1885 (reprinted Dover, 1964).
Relevance. Diophantus's integer-only equations are the historical seed of every subsequent attempt to lock physical predictions to integer constraints. In the constitutional reading of POS-6 OGN, the OGN-5 ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ is the unique solution of a *Diophantine system* in this strict ancient sense. First cited in §19.

Dirac, P. A. M. (1930). *The Principles of Quantum Mechanics*. Oxford University Press.
Relevance. A classic axiomatic presentation of quantum theory. We cite it to underscore that "axioms" in quantum mechanics have historically mixed dynamics with measurement rules, motivating a more explicit separation between axioms and postulates. First cited in §7.

Dirac, P. A. M. (1931). Quantised singularities in the electromagnetic field. *Proceedings of the Royal Society A*, *133*(821), 60–72. https://doi.org/10.1098/rspa.1931.0130
Relevance. Dirac's monopole argument is a classic demonstration that charge quantization can follow from topology and consistency conditions. It provides historical precedent for AX-2's mechanism "quantization from geometry/topology" (e.g. from compact holonomy sectors in the bulk). First cited in §6.

Doplicher, S., Haag, R., & Roberts, J. E. (1971). Local observables and particle statistics, I. *Communications in Mathematical Physics*, *23*, 199–230.
Relevance. The DHR analysis of superselection sectors and statistics from local observables. In the constitutional reading of POS-4 CP, DHR demonstrates that the entire kinematic structure of

a quantum theory — charges, statistics, gauge group — can be reconstructed from the algebra of local observables and their representations, supporting the algebra-first reading used by GG-Theory. First cited in §14.

Douglas, M. R. (2003). The statistics of string/M theory vacua. *Journal of High Energy Physics*, *2003*(05), 046. https://arxiv.org/abs/hep-th/0303194
Relevance. The "landscape" perspective illustrates a modern form of theory-space proliferation: many consistent-looking vacua and effective theories appear, and selecting Nature's point requires additional principles. We cite it as motivation for MSMF: an axiomatic constraint intended to collapse landscapes into derived, minimal-ledger predictions. First cited in §8.

Dyson, F. J. (1949). The radiation theories of Tomonaga, Schwinger, and Feynman. *Physical Review*, *75*(3), 486–502. https://doi.org/10.1103/PhysRev.75.486
Relevance. Dyson's 1949 paper unified the apparently independent renormalization programs of Tomonaga (Tokyo), Schwinger (Harvard), and Feynman (Cornell) into a single coherent framework, demonstrating that the three approaches yield identical observable predictions for QED. This was the founding moment of renormalized quantum field theory. We cite it in POS-5 (RG) as the original technical achievement from which the renormalization-group flow concept later emerged. First cited in §18.

Ehresmann, C. (1950). Les connexions infinitésimales dans un espace fibré différentiable. In *Colloque de Topologie (Espaces Fibrés), Bruxelles, 1950*, 29–55.
Relevance. The founding definition of a connection on a fiber bundle, and with it the rigorous mathematical form of GGEP (AX-2): a gauge field is a connection, a field strength a curvature, a gauge phase a holonomy. Cited under AX-2 milestone (7). First cited in §6.

Einstein, A. (1905). Zur Elektrodynamik bewegter Körper. *Annalen der Physik*, *17*, 891–921. https://doi.org/10.1002/andp.19053221004
Relevance. Einstein's operational reconstruction of simultaneity and inertial frames exemplifies a successful "axiom-like" intervention in physics: changing the admissibility rules for coordinates and clocks reshaped all of kinematics. We cite it to justify treating operational definitions (OGGEP) as constitutional. First cited in §1.

Einstein, A. (1907). Über das Relativitätsprinzip und die aus demselben gezogenen Folgerungen. *Jahrbuch der Radioaktivität und Elektronik*, *4*, 411–462.
Relevance. This early paper contains key steps toward the equivalence-principle reasoning that culminated in general relativity. It anchors AX-2 historically: GGEP is explicitly framed as a generalization of equivalence-principle logic from gravity to a composite geometry+gauge connection. First cited in §6.

Einstein, A. (1915). Die Feldgleichungen der Gravitation. *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin*, 844–847.
Relevance. The field equations of GR encode gravity as geometry and are historically rooted in the equivalence principle. We cite GR as a prototype of "geometrization" and as a precedent for extending an equivalence principle to a more unified object (GGEP). First cited in §1.

Einstein, A. (1916). Die Grundlage der allgemeinen Relativitätstheorie. *Annalen der Physik*, *49*, 769–822. https://doi.org/10.1002/andp.19163540702

Relevance. Einstein's 1916 exposition gives the mature geometric formulation of GR and its equivalence-principle logic. We cite it as the historical anchor for AX-2: GGEP upgrades the equivalence principle from "gravity only" to "gravity + gauge as one composite connection." First cited in §5.

Einstein, A. (1933). On the method of theoretical physics. The Herbert Spencer Lecture, Oxford, 10 June 1933. Reprinted in *Philosophy of Science* **1**(2), 163–169 (1934).

Relevance. Einstein's celebrated statement that "a theorem which at present cannot be based upon anything more than upon a faith in the simplicity, i.e. intelligibility, of nature" must nevertheless guide the working physicist. In the constitutional reading of POS-6 OGN, Einstein 1933 is the deepest twentieth- century philosophical articulation of the Occam-razor discipline that POS-6 elevates from preference to axiom. First cited in §19.

Einstein, A., Podolsky, B., and Rosen, N. (1935). Can quantum-mechanical description of physical reality be considered complete? *Physical Review*, *47*, 777–780. https://doi.org/10.1103/PhysRev.47.777

Relevance. The Einstein–Podolsky–Rosen paper of 1935 posed the completeness problem of quantum mechanics — whether the wavefunction is a complete description of physical reality or whether further hidden variables are required. In the AX-3 lineage, the EPR argument is the historical pivot at which the question of *what gets registered as a measurement outcome* became a central foundational question. The constitutional answer is that the boundary record (via the operational dictionary $\mathcal{D}$) is what physics speaks of; the bulk-side $\mathcal{H}_{\mathrm{Bulk}}$ does not need to match the boundary's $\mathcal{H}_{\mathrm{Bdy}}$, and the EPR completeness question is resolved by recognizing that completeness is a property of the operational compiler. First cited in §7.

Euclid. (c. 300 BCE). *Elements*. (Various modern editions and translations).

Relevance. Euclid's axiomatic method is the historical prototype for a "constitution" of a scientific domain. The present paper explicitly aims to play a similar role for GG-Theory: a short axiom/postulate set that generates an extensive theorem stack. First cited in §1.1.

Euler, L. (1744). *Methodus inveniendi lineas curvas maximi minimive proprietate gaudentes, sive solutio problematis isoperimetrici latissimo sensu accepti*. Lausanne: Bousquet.

Relevance. Euler's *Methodus inveniendi* established the calculus of variations as a rigorous mathematical discipline. In the constitutional reading of POS-2 UEP, Euler is the historical hinge between Maupertuis's stated principle of least action and Lagrange's full analytical apparatus — without Euler's calculus of variations the modern variational engine of physics would not exist. First cited in §15.

Faraday, M. (1845). On the magnetisation of light and the illumination of magnetic lines of force. *Philosophical Transactions of the Royal Society of London*, *136*, 1–20 (read November 1845).

Relevance. Faraday's discovery that magnetic fields rotate the polarization of light — the first experimental hint that the electromagnetic potential carries genuinely physical information beyond what is locally encoded in the field strengths. In the constitutional reading of POS-1 GI, Faraday's intuition of "tubes of force" as physical objects is the deepest historical ancestor of the modern bundle-theoretic reading of gauge fields. First cited in §14.

Fermat, P. (1662). *Synthesis ad refractiones.* Manuscript, communicated in correspondence with M. de la Chambre; published posthumously. Modern discussion in Sabra, *Theories of Light from Descartes to Newton*, Cambridge University Press, 1981.
Relevance. Fermat's principle of least time: the historical seed of every variational principle in physics. In the constitutional reading of POS-2 UEP, Fermat 1662 is the deepest ancestor of the unified extremal principle, predating Maupertuis by eighty years and Hamilton by nearly two centuries. First cited in §15.

Feyerabend, P. (1975). *Against Method: Outline of an Anarchistic Theory of Knowledge.* London: New Left Books.
Relevance. Feyerabend's radical critique of falsificationism. In the constitutional reading of POS-7 MF, Feyerabend is cited together with Kuhn and Lakatos as the philosophical context against which Popper's naive demarcation criterion was refined; the modern pre-registration discipline embedded in POS-7 is a direct working-physics response to these philosophical complications. First cited in §20.

Feynman, R. P. (1948). Space-time approach to non-relativistic quantum mechanics. *Reviews of Modern Physics*, *20*(2), 367–387. https://doi.org/10.1103/RevModPhys.20.367
Relevance. The path integral makes the connection between action extremization and quantum amplitudes explicit (stationary phase in the classical limit). We cite it in POS-2 to link PLA to quantum mechanics within a single extremal framework. First cited in §15.

Feynman, R. P. (1949). Space-time approach to quantum electrodynamics. *Physical Review*, *76*(6), 769–789. https://doi.org/10.1103/PhysRev.76.769
Relevance. Feynman's 1949 reformulation of QED in terms of space-time diagrams and propagators provided the diagrammatic technology that made all subsequent quantum-field-theory calculations practical. The renormalization procedure is constructed by absorbing divergent loop integrals into redefinitions of the bare mass and charge. We cite it in POS-5 as one of the three foundational QED-renormalization papers (Tomonaga 1946, Schwinger 1948, Feynman 1949) from which the renormalization-group concept later emerged. First cited in §18.

Feynman, R. P., & Vernon, F. L. (1963). The theory of a general quantum system interacting with a linear dissipative system. *Annals of Physics, 24*, 118–173.
Relevance. Introduces the influence functional for open quantum systems, a key tool for deriving reduced dynamics and decoherence. It is cited to connect OGGEP/GDOS-style open evolution to established path-integral machinery. First cited in §7.

Frauchiger, D., & Renner, R. (2018). Quantum theory cannot consistently describe the use of itself. *Nature Communications*, *9*, 3711. https://doi.org/10.1038/s41467-018-05739-8

Relevance. The Frauchiger-Renner thought experiment is the sharpest recent no-go statement against interpretation-free quantum mechanics: it argues that any single universal interpretation is inconsistent under iterated agent-based measurement. In the constitutional reading of AX-3 OGGEP, the Frauchiger-Renner paradox is the boundary report of an attempt to compose two OGGEP-projections at different scales without honoring the operational dictionary's CPTP discipline; once the projections are required to be admissible CPTP channels and the measurement contract is registered, the paradox dissolves into a specification of which channel the second observer is actually running. Cited as the canonical modern target of the constitutional answer. First cited in §D.8.

Freed, D. S. (2019). Anomalies and invertible field theories. *Geometry and Topology of Quantum Field Theories*, Lecture Notes (Park City Mathematics Institute). https://arxiv.org/abs/1404.7224
Relevance. Freed's modern categorical formulation of anomalies as invertible (n+1)-dimensional topological field theories. In the constitutional reading of POS-3 AF, this work makes the geometric-origin-of-anomaly principle precise: every boundary anomaly is the partition function of a bulk invertible TQFT, so anomaly cancellation is a bulk-side topological identity. First cited in §16.

Freed, D. S., Hopkins, M. J., & Teleman, C. (2010). Loop groups and twisted K-theory III. *Annals of Mathematics*, *174*, 947–1007. https://arxiv.org/abs/math/0312155
Relevance. The Freed–Hopkins–Teleman theorem relating twisted equivariant K-theory of a compact Lie group to its Verlinde algebra. In the constitutional reading of POS-3 AF, this work is the categorical scaffolding on which the modern anomaly-as-TQFT picture rests, supplying the technical foundation for the bulk-side classification of admissible gauge structures. First cited in §16.

Freedman, S. J., & Clauser, J. F. (1972). Experimental test of local hidden-variable theories. *Physical Review Letters*, *28*, 938–941. https://doi.org/10.1103/PhysRevLett.28.938
Relevance. The first experimental confirmation of Bell-inequality violation. In the constitutional reading of POS-7 MF, Freedman–Clauser is cited as the historical anchor for the empirical-physics practice of pre-declaring a kill criterion ("if the inequality holds, quantum mechanics is wrong") and then running the registered test. First cited in §20.

Freidlin, M. I., & Wentzell, A. D. (1998). *Random Perturbations of Dynamical Systems* (2nd ed.). New York: Springer. https://doi.org/10.1007/978-1-4612-0611-5
Relevance. Freidlin–Wentzell theory provides a rigorous large-deviation framework in which stochastic open-system trajectories concentrate near minimizers of an action functional. We cite it as mathematical background for POS-2 (UEP), supporting the claim that "least-action" logic persists in open/noisy systems as a most-probable-path extremal principle. First cited in §15.

Friston, K. (2010). The free-energy principle: a unified brain theory? *Nature Reviews Neuroscience*, *11*(2), 127–138. https://doi.org/10.1038/nrn2787
Relevance. Friston's free-energy principle is a prominent modern attempt to unify perception, learning, and action by variational optimization. We cite it in the bridge to GG-A5-GDOS in

(Arisaka, 2026, A5-GDOS) to illustrate that "free-energy-like" scalar functionals already function as organizing principles in neuroscience, motivating the GG-Theory claim that GFF and GDOS provide a systematic open-system generalization with explicit gauge/geometry and falsifiability constraints. First cited in §15.

Fujikawa, K. (1979). Path-integral measure for gauge-invariant fermion theories. *Physical Review Letters*, *42*, 1195–1198.
Relevance. Shows how anomalies arise from the non-invariance of the fermionic path-integral measure, providing a clean and widely used derivation. This is a key technical underpinning of POS-3, which treats anomalies as an axiomatic violation unless canceled by inflow. First cited in §16.

Galilei, G. (1632). *Dialogo sopra i due massimi sistemi del mondo* (*Dialogue Concerning the Two Chief World Systems*). Florence: Landini.
Relevance. Galileo's *Dialogue* of 1632 contains the first explicit statement of the principle of relativity — the famous "ship's cabin" thought experiment in which mechanics inside a uniformly moving ship is indistinguishable from mechanics at rest. In the AX-1 lineage, Galileo's principle is the original recognition that the laws of physics carry a kinematic invariance group: there is no preferred frame, and any admissible kernel must respect that invariance. Locality and causality, as we now understand them, are the relativistic refinement of Galileo's insight. First cited in §5.

Gardiner, C. W. (2009). *Stochastic Methods: A Handbook for the Natural and Social Sciences* (4th ed.). Springer.
Relevance. A comprehensive reference for stochastic differential equations and the Fokker–Planck formalism. It supports the GDOS "kernel" derivations in the appendices and clarifies positivity-preserving conditions (POS-CP). First cited in §8.

Gell-Mann, M., & Low, F. E. (1954). Quantum electrodynamics at small distances. *Physical Review*, *95*, 1300–1312. https://doi.org/10.1103/PhysRev.95.1300
Relevance. The Gell-Mann–Low paper is a foundational early statement of RG ideas in quantum field theory. It is cited as historical background for POS-5 (RG): scale dependence must be organized systematically, and physical content must be extracted in an RG-consistent way. First cited in §18.

Georgi, H., & Glashow, S. L. (1974). Unity of all elementary-particle forces. *Physical Review Letters*, *32*(8), 438–441. doi:10.1103/PhysRevLett.32.438.
Relevance. The SU(5) grand-unification proposal is a canonical example of symmetry-driven unification beyond the Standard Model. GG-Theory references it historically, but differs axiomatically by treating gauge–gravity unification through a composite geometric connection (GGEP) and by enforcing anomaly/normalization constraints as admissibility filters. First cited in §8.

Giustina, M., et al. (2015). Significant-loophole-free test of Bell's theorem with entangled photons. *Physical Review Letters*, *115*(25), 250401. https://doi.org/10.1103/PhysRevLett.115.250401
Relevance. The Vienna loophole-free Bell test of 2015, performed in parallel with the Delft (Hensen et al., 2015) and NIST experiments. We cite it together with Aspect (1982) and Hensen

(2015) at every axiomatic invocation of AX-1 LC as the laboratory closure of the locality crisis identified by Bell (1964). First cited in §5.

Glashow, S. L. (1961). Partial-symmetries of weak interactions. *Nuclear Physics*, *22*, 579–588. https://doi.org/10.1016/0029-5582(61)90469-2
Relevance. Glashow's gauge unification of electromagnetic and weak interactions initiated the electroweak structure completed by Weinberg and Salam. We cite these as the historical backbone for POS-1 (Gauge Invariance) and for the claim that symmetry principles organize viable theories. First cited in §1.

Gorini, V., Kossakowski, A., & Sudarshan, E. C. G. (1976). Completely positive dynamical semigroups of N-level systems. *Journal of Mathematical Physics*, *17*(5), 821–825.
Relevance. Along with Lindblad's work, this establishes the generator form required for physical open-system quantum evolution. It supports POS-CP and the OGGEP demand that open evolution be part of the foundational dictionary. First cited in §1.

Green, M. B., & Schwarz, J. H. (1984). Anomaly cancellations in supersymmetric $D = 10$ gauge theory and superstring theory. *Physics Letters B*, *149*(1–3), 117–122.
Relevance. Green and Schwarz's 1984 construction is the prototype of bulk-side classical absorption of a boundary anomaly by a B_2-form coupling. In the constitutional reading of POS-3 AF, what Green and Schwarz wrote down in 1984 is the bulk-side classical-topological identity — not a quantum cancellation of a one-loop pathology but a B_2-coupled rewrite of the bulk Bianchi identity descended from Bianchi 1902. The cohort framework occupies exactly this bulk-side classical-topological sector and inherits the $dH_3 = X_4$ structural identity. The quantum-string content that Green–Schwarz *also* buys (graviton vertex operators, α' corrections, perturbative-string apparatus) is a separate physical sector that the cohort axioms neither subsume nor contradict. Cited as the historical anchor for the bulk-side classical-absorption framing of POS-3 AF, with the understanding that the cohort claim is strictly the classical-topological backbone. First cited in §1.3.

Gross, D. J., & Wilczek, F. (1973). Ultraviolet behavior of non-Abelian gauge theories. *Physical Review Letters*, *30*(26), 1343–1346. https://doi.org/10.1103/PhysRevLett.30.1343
Relevance. Asymptotic freedom is a key structural fact about non-Abelian gauge theories and underlies the consistency of QCD. We cite it to emphasize that "viability filters" (renormalizability, RG behavior) are part of what makes gauge theories physically admissible. First cited in §8.

Gubser, S. S., Klebanov, I. R., & Polyakov, A. M. (1998). Gauge theory correlators from non-critical string theory. *Physics Letters B*, *428*(1–2), 105–114. https://arxiv.org/abs/hep-th/9802109
Relevance. Together with Witten's prescription, this paper established the concrete AdS/CFT dictionary relating bulk fields to boundary correlators. We cite it as historical precedent for treating a bulk→boundary export map as part of the theory's definition, which OGGEP generalizes to include explicit measurement semantics. First cited in §6.

Guth, A. H. (1981). Inflationary universe: A possible solution to the horizon and flatness problems. *Physical Review D*, *23*(2), 347–356. https://doi.org/10.1103/PhysRevD.23.347

Relevance. Inflation is the dominant paradigm for early-universe initial conditions. We cite it as a core cosmological motivation: the mechanism is empirically successful yet microphysically underdetermined, supporting the need for a stronger constitution that restricts "allowed" inflationary dynamics and connects them to observation. First cited in §1.2.

Haag, R. (1992). *Local Quantum Physics: Fields, Particles, Algebras* (2nd ed.). Springer. https://doi.org/10.1007/978-3-662-03081-1

Relevance. Haag's formulation of QFT emphasizes locality, causality, and operator-algebraic structure. We cite it to ground AX-1 in the rigorous QFT tradition and to clarify what "locality" means when expressed as constraints on observable algebras. First cited in §1.

Haag, R., & Kastler, D. (1964). An algebraic approach to quantum field theory. *Journal of Mathematical Physics*, *5*, 848–861.

Relevance. The Haag–Kastler axioms for local quantum physics: a net of C^*-algebras of local observables indexed by bounded spacetime regions. In the constitutional reading of POS-4 CP, Haag–Kastler is the canonical algebraic statement of positivity + closure for a relativistic local theory. First cited in §17.

Hamilton, W. R. (1834). On a general method in dynamics. *Philosophical Transactions of the Royal Society of London*, *124*, 247–308. https://doi.org/10.1098/rstl.1834.0017

Relevance. Hamilton's formulation is the modern backbone of the principle of least action and canonical dynamics. We cite it in POS-2 to emphasize that extremal principles historically reorganized mechanics and are a natural candidate for a unification engine. First cited in §8.

Hamilton, W. R. (1835). Second essay on a general method in dynamics. *Philosophical Transactions of the Royal Society of London*, *125*, 95–144.

Relevance. Hamilton's reformulation of mechanics on phase space, introducing what we now call the Hamiltonian and the canonical equations. In the constitutional reading of POS-2 UEP, Hamilton 1835 is the technical bridge from Lagrangian to phase-space formulations and the historical foundation of Hamilton–Jacobi theory on which the WKB limit of POS-2 rests. First cited in §15.

Hardy, G. H., & Ramanujan, S. (1918). Asymptotic formulae in combinatory analysis. *Proceedings of the London Mathematical Society*, *17*, 75–115.

Relevance. The Hardy–Ramanujan circle method for partition counting. In the constitutional reading of POS-6 OGN, Hardy–Ramanujan exemplify the modern arithmetic- representation theory tradition into which the OGN-5 Diophantine constraint $K = M^2 + N^2 + L^2$ naturally fits. First cited in §19.

Harlow, D., & Ooguri, H. (2019). Symmetries in quantum field theory and quantum gravity. *Communications in Mathematical Physics*, *383*, 1669–1804 (published 2021; arXiv 2019). https://arxiv.org/abs/1810.05338

Relevance. The modern technical statement of the "no global symmetry in quantum gravity" conjecture. In the constitutional reading of POS-1 GI, Harlow–Ooguri supplies the contemporary philosophical justification for the primacy of gauge invariance: any apparent global symmetry must, in any consistent UV completion, either be gauged or be broken. First cited in §14.

Hawking, S. W. (1975). Particle creation by black holes. *Communications in Mathematical Physics*, *43*, 199–220.
Relevance. Hawking radiation is a canonical example of an open-system process in fundamental physics: a horizon mediates information/energy exchange between regions, producing an arrow of time in an otherwise unitary theory. We cite it to motivate why GDOS treats openness and operational observation as foundational. First cited in §7.

Heisenberg, W. (1925). Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen. *Zeitschrift für Physik*, *33*(1), 879–893.
Relevance. Matrix mechanics is one of the two founding formulations of quantum theory and exemplifies the radical redefinition of dynamical variables. It sets historical context for treating quantum structure as something potentially geometric. First cited in §1.1.

Heisenberg, W. (1927). Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik. *Zeitschrift für Physik, 43*, 172–198.
Relevance. A primary source for the uncertainty principle and early quantum-measurement ideas. It is cited as part of the historical background for why operational definitions are central to quantum theory. First cited in §7.

Hensen, B., et al. (2015). Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres. *Nature*, *526*(7575), 682–686. https://doi.org/10.1038/nature15759
Relevance. The Delft loophole-free Bell test of 2015, the first to close the locality and detection loopholes simultaneously. We cite it together with Aspect (1982) and Giustina (2015) as the laboratory closure of the locality crisis that motivates AX-1 LC as a constitutional clause rather than a metaphysical claim. First cited in §5.

Heron of Alexandria (c. 1st century CE). *Catoptrica* (on reflection). Recovered through Latin translation and modern editions; see Cohen & Drabkin, *A Source Book in Greek Science*, McGraw-Hill, 1948.
Relevance. Heron's argument that light's path of equal angles minimizes the distance — the first recorded extremal principle in physics. In the constitutional reading of POS-2 UEP, Heron is the deepest ancient ancestor of every subsequent variational principle. First cited in §15.

Hilbert, D. (1915). Die Grundlagen der Physik. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 395–407.
Relevance. Hilbert's variational derivation of general relativity, contemporaneous with Einstein's field equations and the historical context in which Noether developed her theorems. In the constitutional reading of POS-1 GI, Hilbert 1915 is the direct ancestor of Noether 1918 and the foundational example of a gauge theory presented in fully variational form. First cited in §14.

Hopkins, M. J., and Singer, I. M. (2005). Quadratic functions in geometry, topology, and M-theory. *Journal of Differential Geometry*, *70*(3), 329–452. https://doi.org/10.4310/jdg/1143642908

Relevance. Hopkins and Singer built the differential-cohomology machinery — differential characters, quadratic refinements, and the long exact sequences relating them — on which the global anomaly argument of GG-A3-BI6 rests. Where the present paper says that the BI-6 anomaly cancellation is exact rather than perturbative, this is the mathematics that carries the word "exact". First cited in §16.

Hosotani, Y. (1983). Dynamical mass generation by compact extra dimensions. *Physics Letters B*, *126*, 309–313. https://doi.org/10.1016/0370-2693(83)90170-3

Relevance. Hosotani's 1983 paper introduces the mechanism by which a higher-dimensional gauge symmetry is broken to a lower-dimensional subgroup by a non-vanishing vacuum expectation value of the Wilson line wrapping a compact direction. It is the first concrete extra-dimensional realization of AX-2 GGEP: it shows that the holonomy of the gauge connection around a compact direction is itself a dynamical field whose vacuum value selects the low-energy gauge content. The cohort framework's use of the S^1_θ holonomy phase as the carrier of AX-3 OGGEP's hidden-variable content is a direct descendant of the Hosotani construction. First cited in §6.

Hosotani, Y. (1989). Dynamics of non-integrable phases and gauge symmetry breaking. *Annals of Physics (NY)*, *190*, 233–253. https://doi.org/10.1016/0003-4916(89)90015-8

Relevance. Hosotani's 1989 follow-up develops the full systematic treatment of dynamical gauge symmetry breaking via compact-direction Wilson-line holonomy. Together with the 1983 paper, it establishes the compact-holonomy-as-physical-field reading of the gauge connection that AX-2 GGEP axiomatizes. We cite it as the systematic technical reference for the Hosotani mechanism in the AX-2 historical lineage. First cited in §6.

Jarzynski, C. (1997). Nonequilibrium equality for free energy differences. *Physical Review Letters*, *78*(14), 2690–2693.

Relevance. Jarzynski's equality shows that free-energy differences can be inferred from nonequilibrium work statistics. It supports the UEP/GDOS viewpoint that variational/ledger principles remain meaningful and falsifiable far from equilibrium. First cited in §5.

Jaynes, E. T. (1957). Information theory and statistical mechanics. *Physical Review, 106*(4), 620–630. DOI: 10.1103/PhysRev.106.620.

Relevance. Introduces the maximum-entropy (MaxEnt) principle as a constructive variational rule for statistical mechanics. We cite it in POS-2 to connect thermodynamic extremal principles to inference and to motivate treating free-energy/entropy functionals as legitimate variational objects when paired with operational constraints. First cited in §15.

Joos, E., & Zeh, H. D. (1985). The emergence of classical properties through interaction with the environment. *Zeitschrift für Physik B*, *59*(2), 223–243. https://doi.org/10.1007/BF01725541

Relevance. The decisive demonstration that environmental scattering decoheres a system on extraordinarily short timescales — one of the foundational papers of the decoherence program.

We cite it whenever the historical chain Zeh (1970) → Joos & Zeh (1985) → Zurek (1981, 2003) is invoked as the modern recognition that openness is unavoidable, in motivation of AX-3 OGGEP and the axiomatic inversion that elevates openness from corrective layer to foundational law. First cited in §1.

Kadanoff, L. P. (1966). Scaling laws for Ising models near T_c. *Physics Physique Fizika, 2*(6), 263–272. DOI: 10.1103/PhysicsPhysiqueFizika.2.263.
Relevance. An early primary source for scaling and coarse-graining ideas that evolved into modern RG. It motivates POS-5 by showing why scale transformations are structural, not computational tricks. First cited in §18.

Kaluza, T. (1921). Zum Unitätsproblem der Physik. *Sitzungsberichte der Preußischen Akademie der Wissenschaften zu Berlin*, 966–972.
Relevance. Kaluza's proposal that electromagnetism can be interpreted geometrically via an extra dimension is a foundational ancestor of the "gauge as geometry" program. We cite it as historical support for GGEP and for the appearance of extra coordinates as geometric encodings of gauge structure. First cited in §1.7.

Kass, R. E., & Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association*, *90*(430), 773–795. https://doi.org/10.1080/01621459.1995.10476572
Relevance. Kass and Raftery provide a widely cited modern reference for Bayes factors as quantitative evidence measures. We cite it as part of the methodological background for POS-7 (MF): falsifiability can be operationalized through explicit decision thresholds, whether frequentist or Bayesian, but must be specified in advance. First cited in §19.

Klein, O. (1926). Quantentheorie und fünfdimensionale Relativitätstheorie. *Zeitschrift für Physik*, *37*, 895–906. https://doi.org/10.1007/BF01397481
Relevance. Klein introduced compactification and the resulting quantization of momentum in the extra dimension. We cite it for the standard mechanism by which compact geometry yields discrete spectra (used in AX-2 to illustrate "quantization from topology" rather than an imposed quantization rule). First cited in §1.7.

Kobayashi, S., & Nomizu, K. (1963). *Foundations of Differential Geometry* (Vol. 1). Wiley.
Relevance. This classic text provides the rigorous mathematics of principal bundles, connections, curvature, and holonomy. We cite it as a standard reference for the geometric language used in formulating GGEP (composite connection) and in defining curvature/holonomy as invariants. First cited in §6.

Kolmogorov, A. N. (1933). *Grundbegriffe der Wahrscheinlichkeitsrechnung.* Berlin: Springer. English translation: *Foundations of the Theory of Probability*, Chelsea, 1956.
Relevance. Kolmogorov's axiomatization of probability: probability measures on σ-algebras. In the constitutional reading of POS-4 CP, Kolmogorov 1933 is the modern mathematical scaffolding inside which all of POS-4's positivity and closure requirements live. First cited in §17.

Kraus, K. (1971). General state changes in quantum theory. *Annals of Physics*, *64*(2), 311–335. https://doi.org/10.1016/0003-4916(71)90108-4

Relevance. Kraus operators and instruments provide the modern operational semantics of measurement and state update. We cite this work as foundational for AX-3, where measurement is defined axiomatically as a CP instrument produced by the bulk→boundary dictionary. First cited in §5.

Kraus, K. (1983). *States, Effects, and Operations: Fundamental Notions of Quantum Theory.* Springer. https://doi.org/10.1007/978-3-540-39068-5

Relevance. Kraus' monograph systematizes the operational formulation of quantum measurement and dynamics via completely positive maps. AX-3 adopts this language axiomatically by requiring that measurement be defined in terms of instruments and that open evolution be CPTP. First cited in §5.

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions.* University of Chicago Press. Second edition, 1970.

Relevance. Kuhn's analysis of paradigm shifts. In the constitutional reading of POS-7 MF, Kuhn is the philosophical context in which Popper's naive demarcation criterion is refined: the modern empirical-science culture of registered protocols and pre-registered analyses is the working-physics response to the Kuhnian observation that paradigm shifts can otherwise insulate favored theories from falsification. First cited in §20.

Kullback, S., & Leibler, R. A. (1951). On information and sufficiency. *Annals of Mathematical Statistics*, *22*(1), 79–86. https://doi.org/10.1214/aoms/1177729694

Relevance. The KL divergence is the canonical nonnegative functional measuring distinguishability of probability distributions. We cite it because many "free energy" expressions in nonequilibrium physics and inference can be written as KL divergences, providing a clean mathematical bridge for POS-2 (UEP) between thermodynamic and informational extremals. First cited in §20.

Lagrange, J.-L. (1770). Démonstration d'un théorème d'arithmétique. *Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Berlin.*

Relevance. Lagrange's four-square theorem: every positive integer is the sum of at most four squares. In the constitutional reading of POS-6 OGN, this is the direct arithmetic ancestor of the OGN-5 Diophantine constraint $K = M^2 + N^2 + L^2$ — a number-theoretic identity from 1770 appearing in the deepest structural lock of contemporary physics. First cited in §19.

Lagrange, J.-L. (1788). *Mécanique analytique.* Paris: Veuve Desaint.

Relevance. The full analytical recasting of classical mechanics as a variational problem on configuration space. In the constitutional reading of POS-2 UEP, Lagrange 1788 is the synthesis that turned Maupertuis's principle and Euler's calculus of variations into the working mathematical apparatus of theoretical physics. First cited in §15.

Lakatos, I. (1970). Falsification and the methodology of scientific research programmes. In Lakatos & Musgrave (eds.), *Criticism and the Growth of Knowledge*, Cambridge University Press.

Relevance. Lakatos's refinement of Popperian falsifiability to the level of research programs with a "hard core" and protective "auxiliary hypotheses." In the constitutional reading of POS-7 MF, Lakatos is cited as the principal intermediate between Popper's naive demarcation and the modern pre-registration discipline embedded in POS-7. First cited in §20.

Lamb, W. E., & Retherford, R. C. (1947). Fine structure of the hydrogen atom by a microwave method. *Physical Review*, *72*(3), 241–243. https://doi.org/10.1103/PhysRev.72.241
Relevance. The Lamb shift measurement: the empirical anomaly that triggered the development of modern renormalized QED. In the constitutional reading of POS-5 RG, Lamb–Retherford 1947 is the experimental anchor for the entire renormalization program that POS-5 elevates to axiomatic status. First cited in §18.

Landauer, R. (1961). Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development*, *5*(3), 183–191. https://doi.org/10.1147/rd.53.0183
Relevance. Landauer established that erasing one bit costs at least $k_B T \ln 2$ of dissipated heat — the first result to price information in physical currency. In the constitutional reading it is one of the three independent nineteenth- and twentieth-century discoveries that AX-3 OGGEP unifies: Landauer's bound, the Bekenstein–Hawking entropy, and Zurek's einselection are three faces of one axiom. First cited in §7.

Laplace, P.-S. (1812). *Théorie analytique des probabilités*. Paris: Veuve Courcier.
Relevance. Laplace's comprehensive treatise on probability theory. In the constitutional reading of POS-4 CP, Laplace is the historical synthesizer between Bernoulli/Bayes and Kolmogorov: the first complete analytical apparatus for inverse probability, on which all subsequent quantitative inference rests. First cited in §17.

Lindblad, G. (1976). On the generators of quantum dynamical semigroups. *Communications in Mathematical Physics*, *48*(2), 119–130.
Relevance. Lindblad's theorem provides the canonical generator form for Markovian CPTP evolution. It is central to POS-CP and to OGGEP's claim that open-system dynamics belongs in the theory's syntax. First cited in §1.

Linde, A. D. (1982). A new inflationary universe scenario. *Physics Letters B*, *108*(6), 389–393. https://doi.org/10.1016/0370-2693(82)91219-9
Relevance. Linde's work exemplifies the proliferation of inflationary model-building. We cite it to motivate why a "no-extra-dials" principle (MSMF) could be valuable: without axiomatic restrictions, many potentials are admissible and prediction becomes diffuse. First cited in §1.2.

Lorentz, H. A. (1904). Electromagnetic phenomena in a system moving with any velocity smaller than that of light. *Proceedings of the Royal Netherlands Academy of Arts and Sciences*, *6*, 809–831.
Relevance. Lorentz's 1904 paper introduced the transformations that bear his name — the symmetry group under which Maxwell's electromagnetism is form-invariant and which Einstein's 1905 special relativity would elevate to a universal kinematic constraint. We cite it as the immediate technical ancestor of the operational locality and causality content of AX-1 LC. First cited in §5.

Lorenz, L. (1867). Über die Identität der Schwingungen des Lichts mit den elektrischen Strömen. *Annalen der Physik*, *207*, 243–263.

Relevance. Lorenz's gauge condition (often historically attributed to H. A. Lorentz, but introduced by the Danish physicist L. Lorenz in 1867). In the constitutional reading of POS-1 GI, the Lorenz condition is one of the earliest explicit demonstrations that gauge freedom can be partially fixed without altering observables — the first technical instance of gauge fixing. First cited in §14.

Mach, E. (1893). *The Science of Mechanics: A Critical and Historical Account of its Development*, transl. T. J. McCormack. Open Court, La Salle, IL. (German original: 1883.)

Relevance. Mach's 1893 *Science of Mechanics* formulated the relational principle: inertial frames are defined relative to the distribution of distant matter, not to an absolute background. In the AX-4 lineage, Mach's principle is the philosophical ancestor of the anti-tuning ethos: a theory is more honest when its physical content is determined by relational structure rather than by adjustable absolute parameters. AX-4 MSMF is the modern axiomatic refinement of this ancestor: no continuous parameter may remain unforced. First cited in §8.

Maldacena, J. M. (1998). The large N limit of superconformal field theories and supergravity. *Advances in Theoretical and Mathematical Physics*, *2*, 231–252. https://arxiv.org/abs/hep-th/9711200

Relevance. Maldacena's AdS/CFT conjecture is the modern archetype for bulk–boundary duality and motivates the idea that geometry can encode quantum gauge dynamics. We cite it as a historical anchor for the GGEP/OGGEP posture: bulk geometry is not just a classical background, but a structure from which boundary quantum physics and observables can be exported. First cited in §1.3.

Maupertuis, P.-L. M. de (1744). Accord de différentes lois de la nature qui avaient jusqu'ici paru incompatibles. *Mémoires de l'Académie Royale des Sciences de Paris*, 417–426.

Relevance. The first stated principle of least action in mechanics, $\delta \int p\, dq = 0$. In the constitutional reading of POS-2 UEP, Maupertuis 1744 is the foundational articulation of action as the universal currency of dynamics, the direct ancestor of every subsequent variational principle in physics. First cited in §15.

Maxwell, J. C. (1865). A dynamical theory of the electromagnetic field. *Philosophical Transactions of the Royal Society of London*, *155*, 459–512. https://doi.org/10.1098/rstl.1865.0008

Relevance. The first complete unified-field constitution: four equations folding electricity, magnetism, and the optics of light into a single coherent picture. We cite Maxwell as the historical precedent for the AX-2 GGEP stance that gauge structure and geometry should be treated as facets of a single composite object rather than as independent ingredients written together. First cited in §1.1.

Minkowski, H. (1908). Raum und Zeit. In *Jahresbericht der Deutschen Mathematiker-Vereinigung* (published 1909); English translation in *The Principle of Relativity* (Dover).

Relevance. Minkowski's spacetime formalism makes causality geometric via the light cone. AX-1 inherits this causal structure and exports it to operational open-system evolution: the admissible record must respect the Minkowski/relativistic notion of causal order. First cited in §1.7.

Naimark, M. A. (1940). Spectral functions of a symmetric operator. *Izvestiya Akademii Nauk SSSR, Seriya Matematicheskaya*, *4*, 277–318.
Relevance. Naimark's dilation theorem: every POVM on a Hilbert space is the compression of a PVM on a larger space. In the constitutional reading of POS-4 CP, Naimark 1940 is the structural foundation of operationally-defined measurement and the mathematical precondition for treating instruments and POVMs as the basic objects of physics. First cited in §17.

Nakahara, M. (2003). *Geometry, Topology and Physics* (2nd ed.). Institute of Physics Publishing.
Relevance. Nakahara's text is a widely used bridge between modern geometry/topology and physical gauge theories. It supports AX-2's emphasis that gauge and geometric data are naturally expressed as connections and curvatures, and it provides background for topological routes to quantization. First cited in §6.

Newton, I. (1687). *Philosophiæ Naturalis Principia Mathematica*. Jussu Societatis Regiæ ac Typis Josephi Streater.
Relevance. Newton's definitions and laws were a prototypical axiom system for mechanics, converting astronomy into dynamics and setting the model for "principles → equations → predictions." We cite it as precedent for framing GG-Theory as a constitution that will be cited across later technical papers. First cited in §1.1.

Neyman, J., & Pearson, E. S. (1933). On the problem of the most efficient tests of statistical hypotheses. *Philosophical Transactions of the Royal Society A*, *231*, 289–337. https://doi.org/10.1098/rsta.1933.0009
Relevance. Neyman and Pearson formalized hypothesis testing and error control, which underlies how modern sciences define and enforce rejection criteria. We cite it as historical/statistical background for POS-7 (MF), where every claim must declare an explicit kill criterion with controlled error rates or equivalent auditing logic. First cited in §20.

Nicolis, G., & Prigogine, I. (1977). *Self-Organization in Nonequilibrium Systems*. Wiley.
Relevance. A classic monograph on dissipative structures and nonequilibrium self-organization. It provides historical and mathematical grounding for the idea that open systems generically develop attractors and phases under driving—a key theme of GDOS. First cited in §15.

Nielsen, M. A., & Chuang, I. L. (2010). *Quantum Computation and Quantum Information* (10th Anniversary ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511976667
Relevance. This book codifies the operational viewpoint of quantum theory (states, channels, POVMs) that is closest to the GG-Theory demand that measurement is a defined map rather than a philosophical add-on. We cite it to support the operational language used in motivating OGGEP and POS-7. First cited in §5.

Noether, E. (1918). Invariante Variationsprobleme. *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse*, 235–257.

Relevance. Noether's theorem is the clearest statement that symmetry is not optional: it has measurable conservation consequences. This motivates POS-GI as the first admissibility rule and supports the axiomatic emphasis on symmetry. First cited in §1.1.

Occam, W. of (c. 1320s). *Summa logicae* and *Quodlibetal Questions*. Modern discussion in Boehner, *Ockham: Philosophical Writings*, Nelson, 1957.
Relevance. The principle "*numquam ponenda est pluralitas sine necessitate*" — multiplicity is never to be posited without necessity. In the constitutional reading of POS-6 OGN, William of Occam is the deepest philosophical ancestor of the Occam-gauge-normalization discipline, which POS-6 elevates from a methodological preference to an axiomatic filter. First cited in §19.

Onsager, L. (1931). Reciprocal relations in irreversible processes I. *Physical Review*, *37*, 405–426. https://doi.org/10.1103/PhysRev.37.405
Relevance. Onsager's reciprocity and variational viewpoint provide a foundational extremal structure for near-equilibrium nonequilibrium thermodynamics. We cite it as historical and mathematical background for POS-2 (UEP), supporting the statement that open-system dissipation can be generated by a variational principle (minimum dissipation / gradient flow). First cited in §15.

Onsager, L., & Machlup, S. (1953). Fluctuations and irreversible processes. *Physical Review, 91*(6), 1505–1512. DOI: 10.1103/PhysRev.91.1505.
Relevance. Introduces an action-like functional for stochastic trajectories near equilibrium, providing a bridge between variational principles and stochastic thermodynamics. It supports POS-2 (UEP) in the open-system regime by showing how "least action" persists as a most-probable-path principle for noisy dynamics. First cited in §15.

Ozawa, M. (1984). Quantum measuring processes of continuous observables. *Journal of Mathematical Physics*, *25*(1), 79–87. https://doi.org/10.1063/1.526000
Relevance. Ozawa developed the instrument-based formalism for measurements beyond ideal projective cases. This supports AX-3's insistence that measurement be defined operationally (as an instrument), which is essential for exporting the framework to realistic open systems. First cited in §5.

Padmanabhan, T. (2010). Thermodynamical aspects of gravity: new insights. *Reports on Progress in Physics*, *73*, 046901. https://doi.org/10.1088/0034-4885/73/4/046901
Relevance. Padmanabhan's review of the thermodynamic structure of gravity (Jacobson 1995 onward) provides the systematic case that the Einstein equations can be read as an equation of state. In the constitutional reading of AX-2 GGEP, this is the most technically developed version of the "gravity is emergent" counter-stance; the cohort framework takes the opposite view (geometry primitive, dynamics derived). Named in Part VI for the same reason as Verlinde 2011. First cited in §36.2.

Page, D. N. (1993). Information in black hole radiation. *Physical Review Letters*, *71*(23), 3743–3746. https://doi.org/10.1103/PhysRevLett.71.3743

Relevance. Page computed the entanglement-entropy curve that an evaporating black hole must follow if the evaporation is unitary — the curve whose recovery from semiclassical gravity the islands formula later achieved. The present paper places the Page curve at Stratum 3 of the constitutional tower, beside the Born rule and the Friston free-energy principle, as one of the three sibling families of openness. First cited in §31.

Particle Data Group (Navas, S., et al.). (2024). Review of Particle Physics. *Physical Review D*, *110*(3), 030001. https://doi.org/10.1103/PhysRevD.110.030001 (See also the PDG online database).
Relevance. The PDG is the canonical source for the Standard Model parameterization and experimental constraints. It supports the motivation that our current fundamental theories contain a significant set of empirical inputs and motivates MSMF/OGN as a push toward reduced dial dependence. First cited in §1.3.

Penington, G., Shenker, S. H., Stanford, D., and Yang, Z. (2020). Replica wormholes and the black hole interior. *Journal of High Energy Physics*, *2022*(3), 205. https://doi.org/10.1007/JHEP03(2022)205
Relevance. The Penington–Shenker–Stanford– Yang companion paper to Almheiri et al. derives the islands formula via replica wormholes, putting the bulk-to-boundary information recovery on a firm calculational footing. Together with Almheiri et al., these two papers complete the twenty-first-century holographic chain — from 't Hooft and Susskind's holographic principle through Maldacena's AdS/CFT correspondence and the Ryu–Takayanagi formula to the Page-curve recovery — that AX-3 OGGEP takes as the operational confirmation of its constitutional reading of measurement as bulk-to-boundary projection. First cited in §7.

Peres, A. (1979). Proposed test for complex versus quaternion quantum theory. *Physical Review Letters*, *42*(11), 683–686. https://doi.org/10.1103/PhysRevLett.42.683
Relevance. Peres proposed the first sharp laboratory discrimination between complex and quaternionic quantum mechanics, via the non-commutativity of successive scattering phases. Cited as the class-defining reference for kill clause (3) of F-Constitution-10 (cohort alias F-Real-1): a confirmed quaternionic-direction deviation from the Born trace form would falsify the minimality leg of L-Constitution-1 (candidate). First cited in §8.5.

Perlmutter, S., et al. (1999). Measurements of Ω and Λ from 42 high-redshift supernovae. *The Astrophysical Journal*, *517*(2), 565–586. https://doi.org/10.1086/307221 https://arxiv.org/abs/astro-ph/9812133
Relevance. Together with Riess et al., this work established the observational evidence for accelerated expansion and nonzero Λ in late-time cosmology. We cite it in the applications/discussion sections to anchor the empirical context for "beyond-Λ" claims in a standard observational milestone. First cited in §1.2.

Peskin, M. E., & Schroeder, D. V. (1995). *An Introduction to Quantum Field Theory*. Westview Press.

Relevance. A standard modern presentation of locality, causality, and renormalization in QFT. It provides background for AX-1's microcausality/locality requirement and for later postulates concerning RG compatibility and scale covariance. First cited in §17.

Planck, M. (1900). Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum. *Verhandlungen der Deutschen Physikalischen Gesellschaft*, *2*, 237–245.
Relevance. Planck's work initiated the quantum revolution and exemplifies how a small modification at the axiomatic level (quantization of energy exchange) can restructure an entire domain. First cited in §1.2.

Planck Collaboration. (2018). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, *641*, A6. https://arxiv.org/abs/1807.06209
Relevance. Precision cosmology strongly constrains the expansion history and composition of the Universe. We cite Planck as representative of the empirical pressure behind the inflation/dark-sector puzzles, and as motivation for a constitution that connects cosmological claims to operational observables with falsifiers. First cited in §1.

Polchinski, J. (1984). Renormalization and effective Lagrangians. *Nuclear Physics B*, *231*, 269–295.
Relevance. A classic effective-field-theory treatment emphasizing RG as a map between effective descriptions. POS-5 treats RG/coarse-graining as a structural operation that must commute with observation (OGGEP), and Polchinski's work is a key reference for this map-based viewpoint. First cited in §18.

Polchinski, J. (1995). Dirichlet-branes and Ramond-Ramond charges. *Physical Review Letters*, *75*(26), 4724–4727.
Relevance. This work helped consolidate modern string theory as a framework with extended objects and dualities. It is a key reference for contemporary quantum gravity and unification programs that GG-Theory compares against in its discussion section. First cited in §1.3.

Polchinski, J. (2004). The cosmological constant and the string landscape. Talk at the 23rd Solvay Conference on Physics (Brussels), Dec 2004. Available as arXiv:hep-th/0603249 (Erice 2006 follow-up). https://arxiv.org/abs/hep-th/0603249
Relevance. The landscape idea is an example of explanatory flexibility that can undermine predictivity. It motivates MSMF and OGN as axiomatic constraints aimed at reducing or eliminating continuous families of equally admissible solutions. First cited in §1.3.

Politzer, H. D. (1973). Reliable perturbative results for strong interactions? *Physical Review Letters*, *30*(26), 1346–1349.
Relevance. Along with Gross–Wilczek, this established asymptotic freedom. It reinforces the centrality of RG structure and motivates scale covariance as an axiomatic requirement. First cited in §8.

Popper, K. (1959). *The Logic of Scientific Discovery*. Hutchinson. (Original work published 1934). https://doi.org/10.4324/9780203994627

Relevance. Popper's falsifiability criterion is a classic articulation of what separates scientific statements from metaphysical ones. We cite it in POS-7 to support the demand that every theorem come with a predeclared operational kill criterion, implemented concretely via instruments and statistical tests. First cited in §20.

Prigogine, I. (1947). *Étude thermodynamique des phénomènes irréversibles.* Liège: Editions Desoer.
Relevance. Prigogine's principle of minimum entropy production in linear non-equilibrium steady states: a boundary-side variational principle for irreversible processes. In the constitutional reading of POS-2 UEP, Prigogine 1947 is the canonical example of how the variational engine of physics extends from closed Lagrangian sectors to open dissipative ones. First cited in §15.

Renou, M.-O., Trillo, D., Weilenmann, M., Le, T. P., Tavakoli, A., Gisin, N., Acín, A., & Navascués, M. (2021). Quantum theory based on real numbers can be experimentally falsified. *Nature*, *600*, 625–629. https://doi.org/10.1038/s41586-021-04160-4
Relevance. The network-Bell theorem and experiment class excluding quantum theory over *unshared* real tensor products. In the constitutional reading the exclusion constrains exactly the unshared case and is satisfied by construction by the shared derived J (T-P4-4 of GG-P4-Real); kill clause (2) of F-Constitution-10 (cohort alias F-Real-1) is this experiment class run in reverse. First cited in §8.5.

Reuter, M. (1998). Nonperturbative evolution equation for quantum gravity. *Physical Review D*, *57*, 971–985. https://doi.org/10.1103/PhysRevD.57.971
Relevance. Reuter's exact-renormalization-group equation for the gravitational effective action launched the *asymptotic-safety* program for quantum gravity: gravity is UV-complete via a non-Gaussian fixed point of the renormalization flow. In the constitutional reading of POS-5 RG, asymptotic safety is a Stratum-2 alternative to the cohort's anomaly-locked 6D bulk: it accepts gauge-covariant gravity but does not yet activate AX-3 OGGEP or AX-4 MSMF. Named in Part VI as a competing program. First cited in §36.2.

Riemann, B. (1854). Über die Hypothesen, welche der Geometrie zu Grunde liegen. *Habilitationsvortrag, Göttingen*; published posthumously in *Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen*, *13* (1868).
Relevance. The founding document of the modern mathematics of curved manifolds and the conceptual leap that turned geometry into a degree of freedom of physical space. We cite Riemann's lecture as the historical precedent for the 6D bulk of GG-6 (Arisaka, 2026, A2-GG6): in the GG-Theory program, the geometry of the bulk is not chosen for convenience but forced by the constitution. First cited in §1.1.

Riess, A. G., et al. (1998). Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The Astronomical Journal*, *116*(3), 1009–1038.
Relevance. One of the two discovery papers for cosmic acceleration. It motivates the claim that cosmology contains deep missing pieces (dark energy) that invite a new foundational viewpoint. First cited in §1.2.

Risken, H. (1989). *The Fokker–Planck Equation: Methods of Solution and Applications* (2nd ed.). Springer.

Relevance. A classic reference for diffusion processes and Fokker–Planck equations. It provides technical background for the GDOS continuity-equation form and its solution methods. First cited in §8.

Rissanen, J. (1978). Modeling by shortest data description. *Automatica*, *14*(5), 465–471. https://doi.org/10.1016/0005-1098(78)90005-5

Relevance. Rissanen's minimum description length principle is another quantitative implementation of Occam's razor. We cite it as methodological background for POS-6 (OGN): the "minimum freedom" doctrine must also eliminate hidden continuous choices in parameterization and normalization. First cited in §8.

Rovelli, C. (2004). *Quantum Gravity*. Cambridge University Press. https://doi.org/10.1017/CBO9780511755804

Relevance. Loop quantum gravity is a canonical example of the "quantize geometry" program. We cite it to emphasize that GG-Theory proposes an inversion: a "geometrization of quantum physics" in which gauge/quantum structures are encoded geometrically and read operationally at the boundary. First cited in §1.3.

Ryu, S. and Takayanagi, T. (2006). Holographic derivation of entanglement entropy from AdS/CFT. *Physical Review Letters*, *96*, 181602. https://doi.org/10.1103/PhysRevLett.96.181602

Relevance. The Ryu–Takayanagi formula expresses the boundary CFT's entanglement entropy as the area of a minimal surface in the bulk AdS geometry. In the AX-3 lineage, Ryu–Takayanagi is the first construction in which a fully operational boundary observable (the entanglement entropy of a boundary region) is computed directly from bulk geometric data, validating the OGGEP thesis that the boundary's operational content is determined by the bulk's geometric content via the projection $\mathcal{D}$. First cited in §7.

Salam, A. (1968). Weak and electromagnetic interactions. In *Elementary Particle Theory* (Proceedings of the Nobel Symposium No. 8), 367–377.

Relevance. Salam's electroweak unification is part of the Standard Model foundation. It is cited here to emphasize that modern physics already depends on strong "admissibility rules" (gauge invariance and renormalizability) even if not presented as an explicit constitution. First cited in §1.

Schlosshauer, M. (2005). Decoherence, the measurement problem, and interpretations of quantum mechanics. *Reviews of Modern Physics, 76*(4), 1267–1305.

Relevance. A modern review clarifying what decoherence explains and what it does not. We cite it to motivate why an operational definition of observation (OGGEP) is valuable in an axiom system. First cited in §7.

Schrödinger, E. (1926). Quantisierung als Eigenwertproblem. *Annalen der Physik*, *79*, 361–376.

Relevance. Wave mechanics provides the second founding formulation of quantum theory. It anchors the historical background for the measurement issue: the wavefunction becomes a central object whose operational status requires axiomatic clarification. First cited in §1.1.

Schwinger, J. (1948). Quantum electrodynamics. I. A covariant formulation. *Physical Review*, *74*(10), 1439–1461. https://doi.org/10.1103/PhysRev.74.1439

Relevance. Schwinger's 1948 covariant formulation of QED was, with Tomonaga's 1946 paper, the first systematic treatment of mass and charge renormalization in a relativistic field theory. The procedure absorbs divergent loop integrals into redefinitions of bare parameters, leaving finite physical predictions for the anomalous magnetic moment of the electron and the Lamb shift. We cite it in POS-5 (RG) as one of the three foundational QED-renormalization papers (Tomonaga 1946, Schwinger 1948, Feynman 1949). First cited in §18.

Seifert, U. (2012). Stochastic thermodynamics, fluctuation theorems and molecular machines. *Reports on Progress in Physics*, *75*(12), 126001. https://doi.org/10.1088/0034-4885/75/12/126001

Relevance. Stochastic thermodynamics extends thermodynamic concepts to small fluctuating open systems and provides precise expressions for entropy production and nonequilibrium work. We cite it for the appendix toy models that connect GDOS-style open dynamics to measurable entropy production and for motivating POS-2's open-system extremal forms. First cited in §5.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, *27*, 379–423, 623–656.

Relevance. Shannon's information theory provides a quantitative language for "entropy" and information flow. Because GG-Theory aims to export a single operational grammar across sciences, information-theoretic quantities become natural candidates for inclusion in the open-system ledger (GDOS) implied by OGGEP. First cited in §19.

Sinha, U., Couteau, C., Jennewein, T., Laflamme, R., & Weihs, G. (2010). Ruling out multi-order interference in quantum mechanics. *Science*, *329*(5990), 418–421. https://doi.org/10.1126/science.1190545

Relevance. The three-slit bound on the Sorkin parameter: genuine three-path interference is consistent with zero, as the Born trace form requires. Cited as the operational anchor of kill clause (3) of F-Constitution-10 (cohort alias F-Real-1) — the quaternionic-excess direction of Born deviations is the live kill against L-Constitution-1 (candidate). First cited in §8.5.

Slavnov, A. A. (1972). Ward identities in gauge theories. *Theoretical and Mathematical Physics*, *10*(2), 99–104. https://doi.org/10.1007/BF01090719

Relevance. Slavnov's 1972 paper extends the Ward–Takahashi identities of QED to non-Abelian gauge theory, producing the Slavnov–Taylor identities that BRST cohomology later cast as off-shell algebraic relations among the renormalized vertex functions. These identities are the operational diagnostic that the gauge bundle's geometric content registers correctly at the boundary effective-action level; they are the bridge between AX-2 GGEP's bulk-side principle and AX-3 OGGEP's boundary-side operational dictionary, and they make non-Abelian renormalizability possible. First cited in §6.

Sober, E. (2015). *Ockham's Razors: A User's Manual.* Cambridge: Cambridge University Press.
Relevance. A modern analysis of simplicity principles (Occam's razor) and how they function in scientific inference. POS-6 (OGN) and AX-4 (MSMF) elevate simplicity from heuristic to axiomatic restriction by forbidding hidden continuous degrees of freedom and convention drift. First cited in §19.

Stinespring, W. F. (1955). Positive functions on C^*-algebras. *Proceedings of the American Mathematical Society*, *6*(2), 211–216. https://doi.org/10.1090/S0002-9939-1955-0069403-2
Relevance. Stinespring's dilation theorem is the mathematical backbone of quantum channels: CP maps arise from unitary evolution on an enlarged space. We cite it to justify how OGGEP can treat open-system boundary dynamics as fundamental while remaining consistent with microscopic unitarity in the bulk. First cited in §1.1.

Stora, R. (1976). Continuum gauge theories. In *New Developments in Quantum Field Theory and Statistical Mechanics*, Cargèse Lectures (M. Lévy and P. Mitter, eds.), NATO Advanced Study Institutes Series, Plenum Press, 201–224.
Relevance. Stora's introduction of the descent equations relating the gauge anomaly polynomial to Chern–Simons forms via BRST cohomology. In the constitutional reading of POS-3 AF, Stora 1976 is the algebraic-topological scaffolding that turns anomaly classification into a question about a chain complex. First cited in §16.

Streater, R. F., & Wightman, A. S. (1964). *PCT, Spin and Statistics, and All That.* W. A. Benjamin.
Relevance. This book codifies rigorous axioms for relativistic QFT, including microcausality and locality. We cite it as a foundational reference for AX-1's operator-algebraic encoding of locality and causality. First cited in §1.4.

Stueckelberg, E. C. G., & Petermann, A. (1953). La normalisation des constantes dans la théorie des quanta. *Helvetica Physica Acta*, *26*, 499–520.
Relevance. The first recognition that the freedom in renormalization subtractions generates a group action on the space of couplings. In the constitutional reading of POS-5 RG, Stueckelberg–Petermann 1953 is the founding statement of the renormalization group as a structural feature of quantum field theory, predating Gell-Mann and Low. First cited in §18.

Susskind, L. (1979). Dynamics of spontaneous symmetry breaking in the Weinberg–Salam theory. *Physical Review D*, *20*(10), 2619–2625.
Relevance. Early naturalness discussions emphasize that symmetry and scale hierarchies are not independent. This supports the motivation for a constitutional axiom (MSMF) aimed at suppressing unexplained parameter sensitivity. First cited in §1.3.

Susskind, L. (1995). The world as a hologram. *Journal of Mathematical Physics*, *36*(11), 6377–6396. https://arxiv.org/abs/hep-th/9409089

Relevance. Susskind's holographic principle paper is a key historical milestone leading to modern bulk–boundary dualities. We cite it to frame OGGEP as a constitution-level insistence that observation is a bulk→boundary export, generalized beyond correlators to full operational semantics. First cited in §1.3.

Susskind, L. (2003). The anthropic landscape of string theory. *Universe or Multiverse?* (conference contribution). https://arxiv.org/abs/hep-th/0302219
Relevance. The landscape framing represents a modern endpoint of unconstrained model freedom: many vacua, many low-energy effective theories, and selection by anthropic arguments. We cite it as a motivation for MSMF, which aims to restore determinism by bounding freedom and demanding symmetry-driven minimality. First cited in §8.

Symanzik, K. (1970). Small distance behaviour in field theory and power counting. *Communications in Mathematical Physics, 18*(3), 227–246. DOI: 10.1007/BF01649434.
Relevance. A foundational development of renormalization and scaling in quantum field theory. Together with Callan and Wilson, it underpins the modern RG view used by POS-5 and motivates the identification of a log-scale coordinate with flow in the space of effective theories. First cited in §18.

Takahashi, Y. (1957). On the generalized Ward identity. *Nuovo Cimento*, *6*, 371–375. https://doi.org/10.1007/BF02832514
Relevance. Takahashi's 1957 paper extends Ward's 1950 identity to its general form, producing the Ward–Takahashi identities that underlie every textbook proof of QED renormalizability. In the AX-2 historical lineage, the Ward–Takahashi identities are the quantum-loop expression of Noether's second theorem in the Abelian gauge sector — the operational confirmation that the gauge bundle's geometric content is preserved by the quantum effective action. First cited in §6.

Taylor, J. C. (1971). Ward identities and charge renormalization of the Yang–Mills field. *Nuclear Physics B*, *33*, 436–444. https://doi.org/10.1016/0550-3213(71)90297-5
Relevance. Taylor's 1971 paper, together with Slavnov's 1972 paper, produces the Slavnov–Taylor identities that establish charge renormalization in Yang–Mills theory. In the AX-2 historical lineage, Taylor's contribution is the non-Abelian generalization of the Ward identity — one of the two papers that together demonstrated that 't Hooft's renormalizability proof for non-Abelian gauge theory is consistent. First cited in §6.

't Hooft, G. (1971). Renormalizable Lagrangians for massive Yang–Mills fields. *Nuclear Physics B*, *35*, 167–188.
Relevance. Renormalizability of gauge theories is a historical turning point that made the Standard Model viable. It motivates the view that "admissibility filters" (symmetry + consistency) are as important as the detailed dynamics. First cited in §1.2.

't Hooft, G. (1993). Dimensional reduction in quantum gravity. In *Salamfestschrift* (World Scientific).

Relevance. One of the early modern statements of holography/dimensional reduction. It provides historical background for the idea that a bulk theory may be fully encoded on a lower-dimensional boundary, a central inspiration for OGGEP. First cited in §1.3.

't Hooft, G. (1980). Naturalness, chiral symmetry, and spontaneous chiral symmetry breaking. In G. 't Hooft et al. (Eds.), *Recent Developments in Gauge Theories* (pp. 135–157). Plenum Press. https://doi.org/10.1007/978-1-4684-7571-5_9
Relevance. Naturalness arguments connect small parameters to enhanced symmetry. We cite this as historical background for MSMF: the GG-Constitution pushes the symmetry↔parameter connection to a stronger law, demanding maximal symmetry and forbidding non-protected dials. First cited in §1.3.

't Hooft, G., & Veltman, M. (1972). Regularization and renormalization of gauge fields. *Nuclear Physics B*, *44*(1), 189–213. https://doi.org/10.1016/0550-3213(72)90279-9
Relevance. The renormalizability of non-Abelian gauge theories is a cornerstone of the SM's consistency. We cite it to illustrate a key lesson: deep consistency conditions (not just phenomenological fits) decide what counts as a viable theory. This motivates postulates that function as consistency filters (e.g. anomaly freedom, RG compatibility). First cited in §14.

Tomonaga, S. (1946). On a relativistically invariant formulation of the quantum theory of wave fields. *Progress of Theoretical Physics*, *1*(2), 27–42. https://doi.org/10.1143/PTP.1.27
Relevance. Tomonaga's 1946 paper, written at Tokyo Bunrika University during the war years, provided the first relativistically invariant treatment of QED with the now-standard interaction picture. Together with Schwinger's 1948 covariant formulation and Feynman's 1949 diagrammatic approach (unified by Dyson 1949), it constitutes the founding of renormalized quantum field theory. The three authors shared the 1965 Nobel Prize in Physics for this work. We cite it in POS-5 (RG) as the original technical achievement from which the renormalization-group concept later emerged. First cited in §18.

Touchette, H. (2009). The large deviation approach to statistical mechanics. *Physics Reports* **478**, 1–69. doi:10.1016/j.physrep.2009.05.002.
Relevance. A modern review of large-deviation theory, clarifying how action-like functionals control typical and rare trajectories. It supports POS-UEPby providing a general mathematical framework for extremal principles in open systems. First cited in §15.

Tsirelson, B. S. (1980). Quantum generalizations of Bell's inequality. *Letters in Mathematical Physics*, *4*, 93–100. https://doi.org/10.1007/BF00417500
Relevance. Tsirelson proved that the Bell-CHSH inequality is bounded *above* in quantum mechanics by $|S| \leq 2\sqrt{2}$, the now-canonical Tsirelson bound. This bound is the quantitative content of operational causality in the quantum setting: quantum mechanics maximally violates the classical-local-causality bound by exactly the Tsirelson factor, no more. In the AX-1 lineage, the Tsirelson bound is the quantitative statement that AX-1 LC admits Bell-violating correlations only up to a specific quantum-saturated limit set by the bulk-to-boundary projection. First cited in §5.

Unruh, W. G. (1976). Notes on black-hole evaporation. *Physical Review D*, *14*(4), 870–892. https://doi.org/10.1103/PhysRevD.14.870

Relevance. Unruh's 1976 follow-up paper develops the systematic theory of the accelerated-observer vacuum and the now-canonical Unruh effect. Together with the Davies–Fulling–Unruh paper, it establishes the operational dependence of the boundary record on the choice of boundary frame — the AX-3 lineage's first quantum-field-theoretic confirmation that the bulk-to-boundary projection is genuinely observer-dependent. First cited in §7.

Vafa, C. (2005). The string landscape and the swampland. *arXiv preprint* hep-th/0509212. https://arxiv.org/abs/hep-th/0509212

Relevance. Vafa's 2005 swampland proposal argued that not every consistent-looking low-energy effective theory can be UV-completed to a string theory; the consistent ones form the "landscape," the inconsistent ones the "swampland." In the AX-4 lineage, the swampland program is the recognition that consistency with a deeper UV structure is itself a constitutional admissibility filter; AX-4 MSMF extends this logic from the string-theoretic UV to the full four-axiom constitution, with the cohort's integer OGN-5 ledger as the operational substitute for the swampland constraint. First cited in §8.

Verlinde, E. (2011). On the origin of gravity and the laws of Newton. *Journal of High Energy Physics*, *2011*, 29. https://doi.org/10.1007/JHEP04(2011)029

Relevance. Verlinde's entropic-gravity proposal inverts the standard relation between gravity and entropy: gravity is treated as an emergent thermodynamic phenomenon rather than as a fundamental geometric one. In the constitutional reading of AX-2 GGEP, Verlinde's program stands as the explicit opposite stance to the cohort's: geometry is taken as derived rather than as primitive. Named in Part VI for completeness. First cited in §36.2.

von Neumann, J. (1932). *Mathematische Grundlagen der Quantenmechanik*. Springer.

Relevance. von Neumann formalized quantum theory axiomatically but introduced measurement as an additional process distinct from unitary evolution. This motivates GG-Theory's insistence that measurement be defined as a constitutional axiom/postulate rather than left as a dualistic rule. First cited in §1.1.

Ward, J. C. (1950). An identity in quantum electrodynamics. *Physical Review*, *78*, 182. https://doi.org/10.1103/PhysRev.78.182

Relevance. Ward's identity is the prototype relation showing how gauge symmetry constrains quantum amplitudes. We cite it in POS-1 and POS-4 to emphasize that gauge invariance is not only a classical redundancy but an admissibility condition that has nontrivial quantum consequences. First cited in §6.

Weinberg, S. (1967). A model of leptons. *Physical Review Letters*, *19*(21), 1264–1266. https://doi.org/10.1103/PhysRevLett.19.1264

Relevance. Weinberg's paper, together with Glashow and Salam, established the electroweak gauge theory. We cite it as part of the historical backbone of gauge invariance and spontaneous symmetry breaking, which GG-Theory aims to generalize to open systems via GDOS. First cited in §1.

Weinberg, S. (1989). The cosmological constant problem. *Reviews of Modern Physics*, *61*(1), 1–23. doi:10.1103/RevModPhys.61.1.
Relevance. The cosmological-constant problem is a sharp expression of the "too many dials" tension between quantum field theory and gravity. It motivates the GG-Theory emphasis on MSMF/OGN (no hidden knobs) and on seeking geometric constraints that reduce phenomenological freedom in cosmology. First cited in §8.

Weinberg, S. (1995). *The Quantum Theory of Fields* (Vol. 1: Foundations). Cambridge University Press.
Relevance. Weinberg's axiomatic and symmetry-driven approach to QFT is a key reference for how locality, causality, and gauge invariance constrain admissible theories. AX-1 is aligned with this tradition but extends it by insisting that the same causal discipline apply to open-system operational evolution and measurement outputs. First cited in §16.

Wess, J., & Zumino, B. (1971). Consequences of anomalous Ward identities. *Physics Letters B*, *37*(1), 95–97. https://doi.org/10.1016/0370-2693(71)90582-X
Relevance. Wess and Zumino derived integrability/consistency conditions on gauge anomalies, demonstrating that anomalies have constrained algebraic structure. We cite this work to justify treating anomaly freedom and inflow cancellation as an axiomatic filter (POS-3) rather than a model-dependent afterthought. First cited in §14.

Witten, E. (1983). Global aspects of current algebra. *Nuclear Physics B*, *223*, 422–432.
Relevance. Witten's full development of the Wess–Zumino term as a topological action in chiral effective field theory, including the quantization of its coefficient. In the constitutional reading of POS-3 AF, the Wess–Zumino–Witten action is the canonical worked example of how anomaly inflow generates integer-quantized topological couplings on the boundary. First cited in §16.

Wetterich, C. (1993). Exact evolution equation for the effective average action. *Physics Letters B*, *301*, 90–94. https://doi.org/10.1016/0370-2693(93)90726-X
Relevance. Wetterich's exact functional flow equation for the effective average action. In the constitutional reading of POS-5 RG, Wetterich 1993 is the contemporary computational engine for non-perturbative RG studies, the modern incarnation of Wilson's renormalization group as a functional flow on theory space. First cited in §18.

Weyl, H. (1918). Gravitation und Elektrizität. *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin*, 465–480.
Relevance. Weyl's early gauge ideas represent one of the first attempts to relate geometry and electromagnetism. While historically distinct from modern Yang–Mills theory, it anchors the long-standing theme that interactions may be geometric in origin, a theme AX-2 makes constitutional. First cited in §6.

Wightman, A. S. (1956). Quantum field theory in terms of vacuum expectation values. *Physical Review, 101*(2), 860–866.
Relevance. An early axiomatic formulation of relativistic quantum field theory in which locality and causality appear as precise algebraic/analytic conditions. It supports the microcausality formulation of AX-1. First cited in §1.

Wigner, E. P. (1939). On unitary representations of the inhomogeneous Lorentz group. *Annals of Mathematics*, *40*(1), 149–204. https://doi.org/10.2307/1968551
Relevance. Wigner's classification of particles by symmetry representations established symmetry as the organizing principle of fundamental physics. It motivates AX-4 (MSMF): the search for maximal symmetry is not aesthetic alone, but historically productive in determining the space of admissible physical structures. First cited in §7.

Wigner, E. P. (1961). Remarks on the mind–body question. In *The Scientist Speculates*, ed. I. J. Good (Heinemann, London), pp. 284–302.
Relevance. Wigner's 1961 "Wigner's friend" thought experiment generalizes the von Neumann cut from a single observer to a chain of observers, forcing the question of where exactly the bulk-to-boundary projection takes place. In the AX-3 lineage, Wigner's friend is the foundational scenario that OGGEP resolves by definitional fiat: the projection is the always-on bulk-to-boundary functor $\mathcal{D}$, not a process tied to any particular observer. First cited in §7.

Wilson, K. G. (1971). Renormalization group and critical phenomena. I. Renormalization group and the Kadanoff scaling picture. *Physical Review B*, *4*(9), 3174–3183.
Relevance. Wilson's RG is the prototype of scale-covariant thinking and motivates POS-RG. Because GG-Theory aspires to unify across scales and domains, it demands that coarse-graining and operational measurement commute in a controlled way. First cited in §1.1.

Wilson, K. G. (1974). Confinement of quarks. *Physical Review D*, *10*(8), 2445–2459. https://doi.org/10.1103/PhysRevD.10.2445
Relevance. Wilson's 1974 paper introduces the Wilson loop $W(C) = \mathrm{Tr}\,\mathcal{P}\exp(\oint_C A)$ in lattice gauge theory as the non-perturbative order parameter for confinement: an area law in the confined phase, a perimeter law in the deconfined phase. In the AX-2 historical lineage, the Wilson loop is the operational gauge-invariant observable that registers the holonomy of the gauge connection around any closed curve, and is the first construction in which the geometric content of the connection becomes a quantitative, measurable invariant of the non-perturbative quantum theory. Every later step in the AX-2 lineage — the Hosotani mechanism, the Green–Schwarz construction, the AdS/CFT correspondence, and the cohort framework's use of the Wilson-line phase Θ_H as the hidden variable behind quantum measurement — descends from Wilson's reading of the holonomy as a physical observable. First cited in §6.

Wilson, K. G., & Kogut, J. (1974). The renormalization group and the ϵ expansion. *Physics Reports*, *12*, 75–200.
Relevance. A standard reference for the modern RG viewpoint: coarse-graining as a flow on theory space. POS-5 builds on this picture but adds the axiomatic demand that RG must commute

with the operational dictionary (OGGEP), enabling a geometric RG coordinate in GG-6. First cited in §18.

Witten, E. (1998). Anti-de Sitter space and holography. *Advances in Theoretical and Mathematical Physics*, *2*, 253–291. https://arxiv.org/abs/hep-th/9802150
Relevance. Witten's prescription (together with Gubser–Klebanov–Polyakov and Maldacena) provides the canonical bulk→boundary correlator map. We cite it as a concrete historical anchor for OGGEP's demand that a theory includes a bulk→boundary dictionary, and as motivation for extending that dictionary to operational measurement objects. First cited in §1.3.

Wu, T. T., & Yang, C. N. (1975). Concept of nonintegrable phase factors and global formulation of gauge fields. *Physical Review D*, *12*, 3845–3857. https://doi.org/10.1103/PhysRevD.12.3845
Relevance. The Wu–Yang "dictionary" between gauge-field theory and fiber-bundle geometry. In the constitutional reading of POS-1 GI, Wu–Yang 1975 is the technical bridge between the physicist's A_μ and the mathematician's principal connection, the historical moment at which gauge theory became *geometric*. First cited in §6.

Yang, C. N., & Mills, R. L. (1954). Conservation of isotopic spin and isotopic gauge invariance. *Physical Review*, *96*(1), 191–195. https://doi.org/10.1103/PhysRev.96.191
Relevance. Yang–Mills theory is the modern origin of non-Abelian gauge symmetry. AX-2 builds on the connection/curvature viewpoint of gauge forces and then strengthens it by asserting that gauge and gravity are parts of one composite geometric structure (GGEP). First cited in §1.

Zeh, H. D. (1970). On the interpretation of measurement in quantum theory. *Foundations of Physics*, *1*(1), 69–76. https://doi.org/10.1007/BF00708656
Relevance. The first explicit recognition that realistic quantum systems are inevitably open — coupled to a much larger environment whose accessible degrees of freedom decohere the system on extremely short timescales. We cite Zeh as the founding paper of the decoherence program; AX-3 OGGEP is the axiomatic formulation of the same intuition, with openness elevated from corrective layer to foundational law. First cited in §1.

Zumino, B. (1985). Cohomology of gauge groups: cocycles and Schwinger terms. *Nuclear Physics B*, *253*, 477–493.
Relevance. Zumino's full cohomological treatment of gauge anomalies and Schwinger terms. In the constitutional reading of POS-3 AF, Zumino 1985 supplies the algebraic apparatus that turns the Stora descent equations into a complete classification of admissible anomaly structures. First cited in §16.

Zurek, W. H. (1981). Pointer basis of quantum apparatus: Into what mixture does the wave packet collapse? *Physical Review D*, *24*(6), 1516–1525. https://doi.org/10.1103/PhysRevD.24.1516
Relevance. The original einselection paper: environment-induced superselection picks out a preferred "pointer basis" that survives decoherence. We cite it as the mid-1981 turning point in the decoherence program that established openness as operationally inescapable, motivating AX-3 OGGEP and the GDOS-as-boundary-law thesis. First cited in §1.

Zurek, W. H. (2003). Decoherence, einselection, and the quantum origins of the classical. *Reviews of Modern Physics*, *75*(3), 715–775. https://doi.org/10.1103/RevModPhys.75.715

Relevance. The mature statement of the decoherence program: a mechanism for effective classicality in open systems via environment-induced superselection. We cite it whenever the chain Zeh (1970) → Joos & Zeh (1985) → Zurek (1981, 2003) is invoked, and as the immediate intellectual precedent for elevating openness from corrective layer to constitutional law in AX-3 OGGEP. First cited in §1.