UCLA/Arisaka-GG-P6-Proton
v20.2 — August 22, 2026 — *Particle Branch*

The Proton as the Ground Geometric Attractor of Matter

The Eleven Questions of the Proton, Closed and Fenced within GG-Theory

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Abstract

Nearly everything you have ever weighed is protons and neutrons, and nearly all of that weight is neither. The proton is a seething bound state — three valence quarks awash in gluons and quark–antiquark pairs, its mass almost entirely interaction energy — and yet it presents to the world a single exact mass with zero width, a charge equal and opposite to the electron's to at least twenty-one decimal places, and a spin of exactly one half that its own constituents famously fail to add up to. It has never once been seen to decay, though the great unified theories insisted it must, and detectors built to watch it die — beginning with Kamiokande — have watched in vain for four decades. Its quarks cannot be removed; its excited copies all crumble in an instant while it alone endures.

This paper assembles, within Grand Geometric Theory, a single answer to eleven questions the proton poses: the proton is the Ground Geometric Attractor (GGA) of the baryonic stratum of a six-dimensional geometry, and its baryon number is not a bookkeeping label but a winding of the compact geometry itself — written by the same twist that breaks the unified gauge symmetry and splits the Higgs multiplet. All eleven questions — from the sharp mass to the information charge of the boundary ledger — are read as faces of that one fact, every import cited at its proved grade, every remaining assumption named, every kill criterion stated. The proton has waited a century to be more than a list of accidents; here it is offered as the theorem its silence was always pointing at.

Executive Summary

The question behind this paper is the oldest in the physics of matter, and the most personal one an experimentalist can ask of the substance in his own hands: what *is* a proton, that it should be what it is? It is the most common heavy particle in the universe and the least explained common object in physics. Eleven specific questions have accumulated around it — some for a century, some newly sharpened by GG-Theory itself:

- **Q1** (mass): why does an object that is mostly interaction energy have one exact, zero-width mass?
- **Q2** (charge): why is its charge *exactly* +1 — equal and opposite to the electron's, to 10^{-21}?
- **Q3** (spin): why is its spin exactly 1/2 when its quarks supply only a third — the "spin crisis"?
- **Q4** (confinement): what confines its quarks?
- **Q5** (the absent quark): why has no experiment ever seen a free quark or a fractional charge?
- **Q6** (immortality): why has no proton ever decayed, when unification required it?
- **Q7** (the law): is baryon number an accident, as the Standard Model has it, or a law?
- **Q8** (the twin): why does the neutron exist, sit just 1.293 MeV up-slope, die in fifteen minutes when free — yet live forever inside nuclei?
- **Q9** (the six): why exactly six flavors, and why is precisely one rung of the excited tower eternal?
- **Q10** (the birth): where did the protons come from — why is there matter at all?
- **Q11** (the ledger): what does one baryonic rearrangement cost in information?

Who this paper is for. This paper is written as a review article, for the graduate student at Super-Kamiokande, Hyper-Kamiokande, DUNE, or JUNO — the experimentalist who watches protons for a living and was never told, by silence or by syllabus, *why* the watching stays silent. It is a message from the founder of that watch: the author built Kamiokande — the Kamioka *Nucleon Decay Experiment* — under Masatoshi Koshiba (1979–1985), when the proton's death was the safest prediction in unified physics. It is simultaneously a gateway: every import is proved in the cohort papers it cites, and the status tags are the reading contract — nothing asserted above its price.

The honest standard-physics ledger. The paper front-loads what standard physics genuinely supplies. Q1 has a real partial answer — the lattice computes the mass to percent accuracy and transmutation explains its largeness — but the uniqueness, identity, and value of the ground state are inputs. Q2 has consistency (anomaly cancellation) and, with a GUT embedding, quantization; the electron–proton match itself is unexplained. Q3 has superb decomposition machinery and no reason the total is exact. Q4 and Q5 have overwhelming evidence and no proof. Q6 and Q7 have an accountant's answer: baryon number happens to survive at renormalizable order — an accident nearly every deeper theory breaks. Q8's splitting is computed on the lattice; why a twin at all, and why that direction, are not. Q9 and Q10 are open — the Standard Model's own baryon violation is quantitatively hopeless for the observed asymmetry. Q11 is this framework's own question, stated so it can be killed.

The one fact. Within GG-Theory the eleven have one answer: *the proton is the Ground Geometric Attractor (GGA) of the baryonic stratum* — the unique lowest resting place for three-quark matter on the boundary of the six-dimensional bulk — *and its baryon number is geometry*: the compact cycle carries a discrete twist, locked to the center of the color group, under which every quark mode winds by one third and every baryon by one. Mass is basin depth, priced by the strong scale from the registration $\alpha_s^{-1}(M_Z) = \pi e$ (the Higgs tolls enter at the percent level: $2m_u + m_d \approx 9$ MeV of 938); charge descends from the embedding shared with the electron; spin is the readout label, not a sum; confinement is one gap hypothesis from a theorem (T-P6-4); the free quark is a readout that does not exist; the twin sits one gate up-slope; the six flavors are $N = 3$ doubled; and the single $\mathbb{Z}_3$-twist simultaneously breaks the unified symmetry, evicts the X, Y bosons from the boundary, splits the Higgs doublet from its triplet, and writes baryon number component by component — *one twist, four locks* (T-P6-2), completing the cohort's stability theorem T-SM-60.1 at its stated conditional grade.

The founder's axiom, and the record. The $\mathrm{U}(1)_B$ at the root of it all was *imposed* — a local gauge invariance in deliberate analogy with electromagnetism, the framework's founding act. The idea is Lee and Yang's, from 1955; the field declined it for seventy years, for three reasons that were correct in four dimensions and are load-bearing structure in six. That history is kept as a record of its own in Part VII, in registers that never mix: verified history, cited to print; the framework's chronology, dated as testimony.

Predictions and kill criteria. The paper is killed by: (F-P6-1) a single proton decay, in any channel, at any rate (reach extends an order of magnitude by ∼2040); (F-P6-2) one confirmed free fractional charge; (F-P6-3) an observed n–$\bar{n}$ oscillation; (F-P6-4) a proton–antiproton asymmetry beyond the CPT-paired readout; (F-P6-5) a long-range baryonic force — the equivalence-principle program has been running this search since 1906; (F-P6-6) the information charge's registered kill. The strongest are decidable within the present generation of experiments.

What is new in this paper. (i) The conjunction thesis: no framework has previously explained the eleven as one theorem-complex about one ground state. (ii) The discharge of the stability theorem's load-bearing hypothesis: the obstruction theorem (baryon number is provably *not* a Lie-algebra charge), the center identity $B = t/3$, and the $\mathbb{Z}_3$-lock — the projection-plus-charge computation the Standard-Model paper deferred to this successor. (iii) The dihedral closure: the reflection sector fixed by the CPT companion's theorem, not chosen. (iv) The consistency sentence: the anomaly door that forbids one proton's death is the door that permitted all protons' births — Q6 and Q10 as one equation. (v) The historical record of the founding axiom, in its own Part. (vi) The complete honesty apparatus: every claim graded, every kill priced.

One thread is personal. The author spent his twenties building an instrument to watch for a flash that this paper, forty-eight years later, derives cannot come. The silence was never a null result; it was the discovery. The tank was right, and this paper is its founder's report on what the silence meant: keep watching.

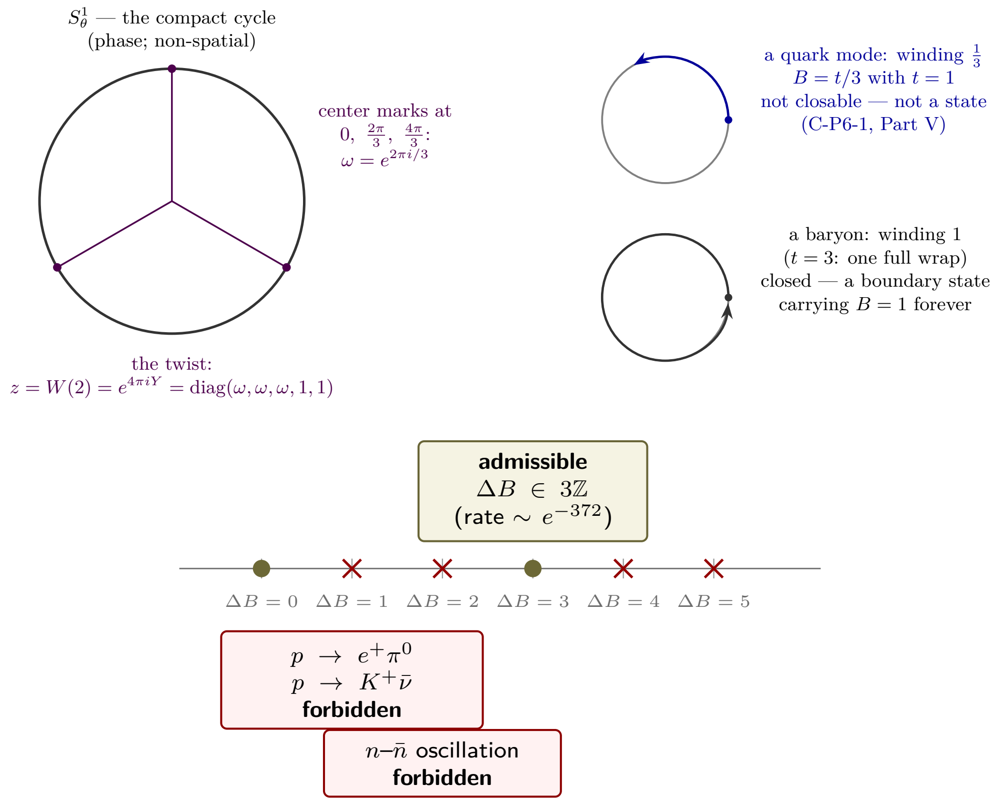
The road through the paper. Sixteen Parts, and it is worth saying in advance which of them carry weight. Part I states the eleven questions and the century that accumulated them, and prices what standard physics genuinely answers. Part II is the inheritance: every result this paper consumes, its home paper, its grade as declared at home, and the Part that spends it — read it once and no later Part will surprise you about what is derived here and what arrives already proved. Parts III through VI are the paper's own work. Part III prices the mass: the baryonic stratum has one terminal basin, the depth of that basin is the strong scale, and the strong scale descends from a single registration with no strong-sector measurement anywhere in the chain. Part IV settles the spin question by refusing its premise — the total is a readout label and was never a sum of parts. Part V takes confinement to the only honest grade available to anyone: a conditional area-law theorem, exact given one named gap hypothesis, with the hypothesis left in the open where a reader can see it. Part VI is the summit — the obstruction theorem, the center identity, the $\mathbb{Z}_3$-lock and the anomaly ledger, which together complete the cohort's stability theorem and leave exactly one door open in the baryon number of the world.

Everything after Part VI is consequence, record, or honesty apparatus. Part VII is the seventy-year record of the founding axiom, kept in registers that never mix. Part VIII walks the neutron down the one gate the winding leaves open within a sector, and Part IX climbs the excited tower above it. Part X imports the birth chain at its home paper's declared grade and not a step stronger. Part XI carries the information charge at candidate grade with its kill criterion quoted. Parts XII and XIII weigh what has been done and what is owed; Part XIV holds the arithmetic; Part XV answers the objections a skeptical reader will already have formed by then; Part XVI is the bibliography. A reader with one hour should read Part I, the ledger table of Part II, and Part VI. A reader who wants to know whether to believe any of it should read Part XII's debt registry first and decide from there.

How to read the grades. Every claim in this paper carries a tag, and the tags are the reading contract rather than decoration. **D** is derived: the argument is complete here or in the cited home paper, and nothing outside the framework is assumed. **D(c)** is derived conditionally, and the conditions are named where the claim is made and again where it is spent — Part VI's completed theorem is D(c) on three finite pins, each a bounded check against deployed cohort apparatus and none of them a new idea. **INT** is an interpretation, offered as one and not as a result. **CAND** is a candidate, admitted only with a registered kill criterion attached. The discipline the tags enforce is the one this paper cares about most: nothing is asserted above its price, and where the honest grade is weak the weakness is stated here rather than left for a reader to find. The confinement Part is the test case — it would have been easy to write as a proof and it is written as a conditional theorem, because that is what it is.

Keywords: proton; baryon number; GGA; baryonic stratum; ground-state uniqueness; $\mathbb{Z}_3$ winding; Stueckelberg-massive $\mathrm{U}(1)_B$; proton stability; $\Delta B \in 3\mathbb{Z}$ selection rule; dimensional transmutation; Λ_{QCD}; mass budget; trace anomaly; spin decomposition; charge radius; form factor; neutron β-decay; gate transit; antiproton; leptogenesis; eleven questions; GG-Theory

The Door That Forbids One Proton's Death — Is the Door That Permitted All Protons' Births



Every canonical proton-decay mode has $\Delta B = 1$; neutron–antineutron oscillation has $\Delta B = 2$; neither integer is a multiple of three, so both are forbidden outright rather than merely suppressed. The thermal reprocessing of Part X lives at $\Delta B \in 3\mathbb{Z}$ and is unaffected. **A single event in either forbidden class falsifies the framework** — and Hyper-Kamiokande will improve the bound on the first class by about an order of magnitude.

Why the proton is still here, and why there is anything for it to be here with. Above: the lock. The sixth dimension is a compact, non-spatial circle, and the unique quantized twist it admits is $z = \mathrm{diag}(\omega, \omega, \omega, 1, 1)$, the center element of color. Under it a lepton travels a whole lap and closes; a single quark travels a third of a lap and cannot close; only three quarks together come back to where they started. That is what baryon number is in this framework — not a bookkeeping label that happens to be conserved, but a winding number, an integer, and nothing continuous acts on the integers. Below: what the lock decides. Baryon number can change only in multiples of three, so proton decay ($\Delta B = 1$) and neutron–antineutron oscillation ($\Delta B = 2$) are not suppressed but forbidden, while the topological vertex at $\Delta B = 3$ stays open at enormous cost — and that surviving door is the one the early universe used. The eighty-year silence in the mines and the existence of the matter doing the listening are one sentence read twice. In full: Figure 16, p. 106, and Figure 18, p. 110.

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Preface

This Preface is addressed, more than to anyone else, to a graduate student on the deck of Super-Kamiokande, in the cavern at Hyper-Kamiokande or DUNE or JUNO — or deciding whether to join one of them — who is wondering what a lifetime of watching silent water is actually worth.

Consider, first, where the watch stands. In 1974, grand unification sentenced the proton to death, and the sentence was the theory's crown jewel: if the forces unify — and the couplings visibly converged — the proton decays. Detectors the size of cathedrals were built underground to collect. The author of this paper was there at the beginning: he spent 1979 to 1985 designing and building the Kamiokande detector — the Kamioka *Nucleon Decay Experiment* — as a doctoral student under Masatoshi Koshiba, in the years when the field expected the flash within a year or two of switch-on (Arisaka et al., 1985). The flash never came. Not that decade, not in the forty years since, not through half a century of accumulated megaton-years. The experiment refused to waste its silence — solar neutrinos, the supernova of 1987, a Nobel Prize, a new astronomy — but the question the tank was named for has stood unanswered in either direction for the length of a career: the proton would not die, and no theory could say why not.

You may also be the reader who kept the questions. You learned early that the proton is made of quarks — two up, one down — and the sentence arrived with the settled tone of an answer. Then, if you looked closer, the answer came apart in your hands. The three quarks account for scarcely one percent of the proton's mass; the rest is a storm of gluons and quark–antiquark pairs that no one can count. Yet this storm presents to every instrument ever built a single exact mass, identical from one proton to the next across the visible universe. Its charge cancels the electron's — a particle two thousand times lighter, with no visible kinship to it — to at least twenty-one decimal places. Its spin is exactly one half, and when the experiments of 1987 went looking for that half among the spins of its quarks, they found a third of it and a crisis. No fractional charge has ever been caught alone. And the proton does not die. Somewhere in your education each of these facts went past, wearing the costume of a technicality. This paper collects them, adds the questions the framework itself has newly sharpened, and takes the eleven of them seriously as a single subject — the way the sister paper (Arisaka, 2026, P3-Electron) took the six oldest questions of the electron.

Now consider what this paper puts on the table. A framework with no adjustable parameters derives that the proton is the *Ground Geometric Attractor* (GGA) of the baryonic stratum — the unique lowest resting place available to three-quark matter — and that its baryon number is not a label the theory carries but a *winding* the geometry cannot drop. From that one fact the paper prices the mass, descends the charge, reads the spin, forbids the free quark, walks the neutron down its gate, doubles the family theorem into six flavors, brings every baryon in the universe through one hot door, and — the emotional center of the whole argument — derives that the flash the tank was built for *cannot come*: the decay is forbidden to all orders, at every rate, forever, at a stated conditional grade with its three remaining pins in plain view. The prediction that built the tank mistook the location of the executioners; the geometry keeps them in the bulk. The silence was never a null result. It was the discovery.

And here is what the theorem does to your watch: it inverts the stakes, and the inversion is the point. In 1980, a flash in the dark would have crowned unification; today, one flash — one event, any channel, any rate — kills this framework outright, with no parameter anywhere to absorb it. Your silence is a measurement, the sharpest ever made of the deepest law this framework contains; and your water, should it ever flash where no muon entered, is the instrument best placed in the world to prove this paper wrong. A framework can pay an experimental community no higher compliment. Honesty requires the other half, and it is the half that makes this science rather than salesmanship: the theory may simply be wrong — and the watch decides that too, either way, within the working lifetime of the experiments now under construction.

How to read the paper, if you are the student described above: start with Part VI (the immortal proton — it is self-contained, and it walks from the mine to the theorem and back); then the falsification table of Part XII, which prices what your experiment can do to this framework; then Part VII, the seventy-year record of the one-letter axiom the theorem discharges — history, kept deliberately apart from proof. Work backwards into the foundations (Parts II–V) as curiosity, not obligation, dictates; the technical appendices of Part XIV are written so that every load-bearing computation can be verified with one sheet of paper. The eleven questions will still be there after your calibration shift — but they are answered differently now, and the difference is checkable.

Part I
The Eleven Questions and Their Century

What has, and has not, been explained since 1917

Every long journey should begin by saying where it is going and why the destination is worth the walk. This opening Part does three things, all in plain sight. It tells the century's story of the proton — how each generation's finest instrument answered one mystery by uncovering finer ones. It states the eleven questions this paper exists to answer, each in its sharpest form, and credits, without reservation, everything standard physics already explains about them. And it signs the contracts: the central claim with its fences around it, and the short list of observations that would kill this paper outright — registered before a single argument is made, because that is the order in which an honest paper does business. Nothing is derived in this Part. It sets the table; the meal is Parts III through XI.

1 The century: how the questions accumulated

The proton's century is usually told as a story of answers. Told honestly, it is a story of questions arriving faster than answers, each new instrument resolving one mystery into finer mysteries.

1917–1919: the nucleus has a piece. Rutherford, firing alpha particles into nitrogen, knocks loose hydrogen nuclei and concludes that the hydrogen nucleus is a constituent of heavier matter; he names it the proton (Rutherford, 1919). For a decade and a half it is possible to believe matter is two particles and done.

1932: the twin. Chadwick finds the neutron (Chadwick, 1932), and with it the first version of Q8: here is a particle heavier than the proton by barely a tenth of a percent, identical to it under the nuclear force, that nevertheless dies in minutes when set free — and lives forever inside a nucleus. The periodic table becomes explicable; the near-degeneracy does not.

1933: the first crack in pointlikeness. Frisch and Stern measure the proton's magnetic moment expecting the Dirac value and find it nearly three times too large, $\mu_p \approx 2.79\,\mu_N$ (Frisch and Stern, 1933). A Dirac point particle it is not. The proton is the first elementary particle caught having an inside — fifteen years before anyone could say what an inside would mean.

1956: the inside has a shape. Hofstadter's electron scattering maps the proton's charge distribution: a smooth cloud roughly 0.8 fm across (Hofstadter, 1956). The question sharpens: a cloud of *what*?

1964–1969: the quarks. Gell-Mann and Zweig organize the hadron zoo with fractionally charged constituents (Gell-Mann, 1964; Zweig, 1964); the SLAC deep-inelastic experiments find hard scattering centers inside the proton (Breidenbach et al., 1969). The constituents are real. They are also, from the first day, strange: no free quark appears in any detector, any cosmic-ray stack, any drop of oil — then or in the eighty years since (Q4, Q5 are born together).

1973: the force that explains and the debt that remains. Asymptotic freedom (Gross and Wilczek, 1973; Politzer, 1973) and the QCD Lagrangian (Fritzsch et al., 1973) give the strong interaction its theory. Two of its properties do the explaining: at short distance the coupling weakens (so SLAC sees quasi-free quarks), and at long distance it grows (so, plausibly, nothing colored escapes). But "plausibly" is load-bearing: confinement has never been derived from the Lagrangian. Wilson's lattice (Wilson, 1974) makes it computable and the computations agree with the world; the mathematical statement — that Yang–Mills theory has a mass gap — remains one of the Clay Millennium Problems, open today. Q4's modern form is fixed here: *the theory of the strong force contains its central qualitative fact only as a numerical observation.*

1974: the death sentence. Georgi and Glashow unify the gauge forces in SU(5) (Georgi and Glashow, 1974), and the unification carries a price tag: the same bosons that relate quarks to leptons mediate proton decay, at rates within reach of a sufficiently patient experiment. The prediction is embraced precisely because it is falsifiable; through the late 1970s the proton's instability is, in the community's estimate, the safest bet unified physics has ever placed.

1979–1985: the tank. Detectors go underground to watch protons die: IMB in a salt mine in Ohio, and Kamiokande in the Kamioka lead-zinc mine — three thousand tonnes of water, a photomultiplier the size of a beach ball at every half-meter, built between 1979 and 1985 by a small group under Masatoshi Koshiba, the detector design and construction carried by the doctoral student whose name appears on this paper's cover (Arisaka et al., 1985). Kamiokande is built to see $p \to e^+\pi^0$ inside a year or two. It does not. What it sees instead — solar neutrinos, and in February 1987 the neutrino burst of Supernova 1987A (Hirata et al., 1987) — founds neutrino astronomy and earns its leader the Nobel Prize; the pivot from nucleon decay to neutrino astronomy is one of the great improvised successes in experimental physics. But the original question did not go away. It hardened.

1987: the spin comes apart. The European Muon Collaboration measures how much of the proton's spin its quarks' spins carry, expecting most of it, and finds a small fraction — consistent, in the first analysis, with none at all (Ashman et al., 1988). Three decades of refinement settle the quark-spin share near thirty percent, with the remainder distributed between gluon spin and orbital motion in proportions that depend on how the question is posed. Q3 acquires its modern name: the spin crisis.

1998–2024: the silence hardens. Super-Kamiokande, fifty thousand tonnes, pushes the proton's partial lifetime into $p \to e^+\pi^0$ beyond 2.4×10^{34} years (Takenaka et al., 2020), with the accumulated exposure now 0.37 megaton-years (Super-Kamiokande, 2024) — more than 10^{24} times the age of the universe. Minimal SU(5) is long dead; its successors retreat scale by scale ahead of the data. Meanwhile the lattice, given only the measured coupling and quark masses, computes the proton's mass from first principles to percent accuracy (Dürr et al., 2008): the ninety-nine percent that is not Higgs is confirmed to be pure interaction energy. And precision experiments sharpen the sharpness itself: the antiproton's charge-to-mass ratio matches the proton's to sixteen parts per trillion (Borchert et al., 2022); the neutron's lifetime is measured to a tenth of a percent — twice, by two methods, giving two answers (877.75 ± 0.28 s in the bottle (Gonzalez et al., 2021), 887.7 ± 2.2 s in the beam (Yue et al., 2013)) whose four-sigma disagreement is its own small open question; the proton's charge radius, after a decade's puzzle between muonic and electronic measurements (Pohl et al., 2010), converges near 0.84 fm.

Today. The Electron–Ion Collider is being built to map, at last, where the proton's spin and mass actually reside (Accardi et al., 2016). Hyper-Kamiokande will carry the decay search another order of magnitude. The century closes where it opened: the most common heavy object in the universe, measured more precisely than any composite system in science, still cannot answer the child's version of any of the eleven questions below.

2 The eleven questions, stated

Each question is stated here in its sharpest form; the honest status table of §3 records what standard physics does and does not supply, and Parts III–XI take them in order (the historical record of Part VII interleaved where the law is proved). The numbering Q1–Q11 is used throughout the paper and in every status ledger.

Q1 — the sharp mass. The proton's mass is 938.272 MeV, identical for every proton, with zero width: it is a true stationary state, not a resonance. Yet by mass it is $\sim 99\%$ gluon field energy and sea, $\sim 1\%$ Higgs-coupled quark mass. Why does an object that is mostly storm present one exact, permanent number? What *fixes* that number?

Q2 — the exact charge. The proton's charge is $+e$ to the precision of the neutrality of hydrogen — better than one part in 10^{21} (Navas et al., 2024). The electron is a lepton; the proton a baryon built of thirds. What enforces exact cancellation between objects with no visible common origin?

Q3 — the undecomposable spin. The proton's spin is exactly $\frac{1}{2}$. Its quarks' spins carry roughly a third of it; the rest is gluon spin and orbital angular momentum in scheme-dependent shares. Why is the total exact and universal when no decomposition of it is?

Q4 — confinement. No colored object has ever crossed a detector. What, precisely, confines the quarks — and why does the theory that predicts every measured hadron property still lack a proof of its own central qualitative fact?

Q5 — the absent free quark. Millikan-style searches, accelerator searches, and bulk-matter searches spanning eighty years have never found a fractional charge (Navas et al., 2024). Is the free quark merely hard to liberate — or is it *not a possible object*?

Q6 — the immortality. No proton has ever been observed to decay: $\tau/B(p \to e^+\pi^0) > 2.4 \times 10^{34}$ yr (Takenaka et al., 2020). The classic unified theories required decay; the proton declined. Is its stability an accident of low-energy bookkeeping, or a law with a mechanism?

Q7 — the law. In the Standard Model baryon number is an *accidental* symmetry: nothing imposes it; it merely happens to survive at renormalizable order, and the electroweak anomaly violates it. Nearly every extension — grand unification, most gravity folklore — breaks it further. Is baryon number an accident, or is it gauged?

Q8 — the twin. The neutron outweighs the proton by 1.293 MeV — a tenth of a percent, the width of a hair between a universe of hydrogen only and a universe with chemistry. Free, it decays in about fifteen minutes (877.75 ± 0.28 s (Gonzalez et al., 2021)); bound, it is stable for at least as long as the proton. Why does the twin exist, why so close, and why does the decay run in exactly the direction it does?

Q9 — the six. The proton's quarks come in six flavors arranged in three families — no more, no less — and the proton itself heads a tower of excited copies (Δ, N^*, the hyperon shelf) every one of which decays in $\sim 10^{-23}$ s while the ground state lives forever. Why six, why three families, and why is precisely one rung of the tower eternal?

Q10 — the birth. The universe contains protons and essentially no antiprotons: about one baryon survived per billion photon pairs. The Standard Model's own baryon-number violation is quantitatively hopeless for producing this. Where did the protons come from?

Q11 — the ledger. GG-Theory locks four currents into one boundary event: energy, electric charge, baryon number, and information (Arisaka, 2026, A7-Qi4). If that locking is right, one baryonic rearrangement is one informational elementary update, priced at $\mathsf{Q_B} = 0.1555$ eV. What does $\mathrm{U}(1)_{Qi}$ mean *for the proton* — and what would falsify it?

Questions Q1–Q6 and Q8–Q10 are the century's; Q7 is the century's question turned structural; Q11 is this framework's own, stated so that it can be killed. Two pairs travel together by design: Q4/Q5 (one mechanism, two faces) and Q6/Q7 (one fact, observational and structural).

3 The honest status table

The discipline of the sister paper is kept: before this framework says a word, the standard answers are credited exactly as far as they go. Table 1 is the paper's contract with the reader; every "open" cell is a claim this paper must either close at a stated grade or leave visibly fenced.

Table 1: The honest status table. Middle column: what standard physics (the Standard Model, QCD, and standard cosmology) genuinely supplies. Right column: what remains unexplained in the standard account. Grades in Parts III–VI and VIII–XI close or fence each row. Eleven rows, one per question, and the two columns are deliberately not in competition: the middle column is written to give the standard account its full due before the right column says what it leaves unexplained. A reader who thinks the right column overstates the gap should read the middle one again first.

Q	**What standard physics supplies**	**What remains unexplained**
Q1	The mass computed to percent accuracy on the lattice from the measured coupling; dimensional transmutation explains why a large mass emerges from nearly massless quarks.	Why a unique exact ground state exists at all; why every readout is identical; the value of the strong scale itself.
Q2	Anomaly cancellation makes the charge assignments *consistent*; with a GUT embedding, quantization follows.	Why the embedding; the SM alone permits but does not explain the electron–proton match; exactness to 10^{-21} is an input.
Q3	The decomposition machinery (helicity distributions, lattice moments); measured shares: quark spin $\sim 30\%$.	Why the total is exactly 1/2 and frame-independent while every decomposition is scheme-dependent; what the spin *is* a property of.
Q4	Lattice QCD demonstrates confinement numerically; the flux-tube picture; asymptotic freedom makes it plausible.	An analytic mechanism; the Clay-grade mass-gap statement; *why* the singlet branch is selected.
Q5	Follows from confinement, if confinement holds.	Whether the free quark is dynamically imprisoned or structurally impossible — the two readings differ, and experiment cannot separate them.
Q6	The SM *accidentally* forbids proton decay at renormalizable order.	Why the accident survives every deeper theory; GUTs generically destroy it; nothing protects it at the Planck seam.
Q7	B conservation observed to extraordinary precision.	The SM provides no principle; B is anomalous and cannot be gauged within the SM's field content.
Q8	$m_n - m_p$ traced to $m_d - m_u$ against electromagnetic self-energy (now computed on the lattice); β-decay theory complete.	Why the splitting is so small; the bottle–beam lifetime discrepancy; why the gate runs in the direction it does.
Q9	Three families measured; six flavors cataloged; the excited spectrum mapped.	Why three; why the tower terminates downward at a stable rung; the SM takes the count as input.
Q10	Sakharov's three conditions (Sakharov, 1967); leptogenesis as a workable mechanism family (Fukugita and Yanagida, 1986).	Which mechanism; every dial; the SM's own CP violation and sphaleron bookkeeping fall short by many orders.
Q11	— (not a standard-physics question).	Everything: the question exists only inside this framework, which must therefore state its kill criterion itself.

4 The central claim, fenced

Here is the paper's one sentence, stated with its fences visible.

> **Central claim.** *On the boundary of the six-dimensional bulk, the color-singlet baryonic stratum has a unique terminal basin — the proton — whose baryon number is the winding of the compact cycle under the* $\mathbb{Z}_3$*-locked descent; the eleven questions of this paper are eleven readings of that basin and that winding.*

The fences, named at once and kept in view throughout:

- The six-dimensional framework itself — the bulk, the boundary law, the attractor machinery — is *inherited*, not re-derived: Part II states every import with its provenance and its conditional clauses attached, from the constitution of GG-A1-Constitution through the Standard-Model derivation of GG-A9-SM.
- The stability theorem this paper completes (Part VI) rests on the Green–Schwarz bookkeeping of GG-A3-BI6 as received, and on three named finite pins (R2, R3) — each a bounded check against deployed cohort apparatus, each stated where it is used, none a new conjecture.
- Confinement (Part V) is engaged at the only honest grade available to anyone: the mathematical statement is open at Clay-Millennium level, and this paper's contribution is a structural reading at its stated grade, not a proof.
- The birth of baryons (Part X) is imported from GG-P5-CPT at that paper's own declared grade — a conditional chain with one named input and one named conjecture — and nothing stronger is claimed here.
- The information charge (Part XI) is carried at the candidate grade of its home paper (Arisaka, 2026, A7-Qi4), kill criterion quoted.

The shape of that argument is the cohort's, and it is worth seeing before the fences: Figure 1 draws it as three boxes, the same three every paper in the program funnels through, with the proton in the box where the sister paper puts the electron.

What is genuinely new in this paper, and claimed as such: the component-resolved realization of baryon number by the $\mathbb{Z}_3$-locked descent (Part VI, with the obstruction theorem that makes it necessary); the ground-attractor reading of the sharp mass and its zero width (Part III); the readout-label resolution of the spin question (Part IV); and the assembly itself — eleven questions that have never before been closed, or honestly fenced, in one place by one structure.

5 What would kill this paper

Pre-registration first, argument after. Each criterion is developed in its owning Part and collected in the falsification table of Part XII.

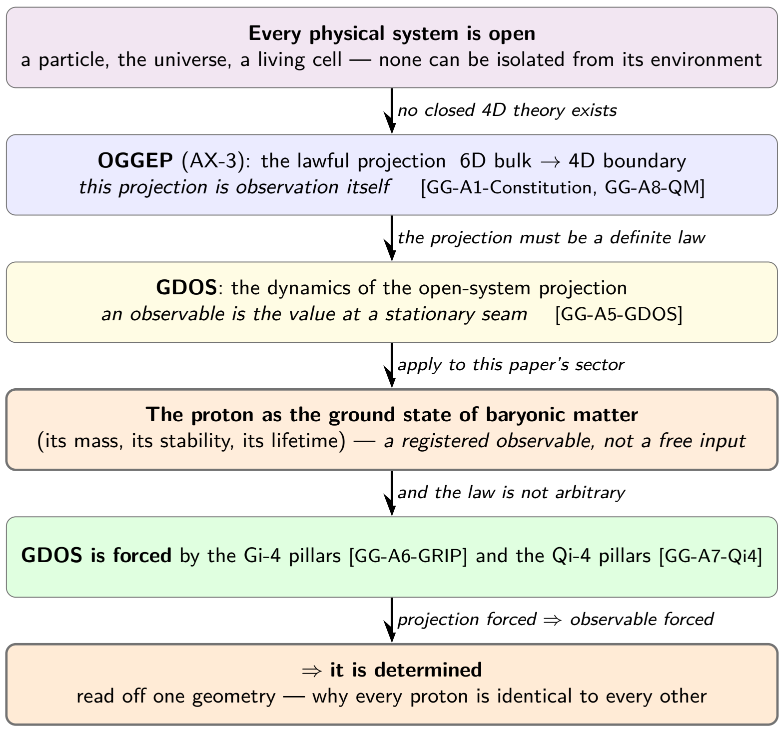


Figure 1: The central claim, as one deductive funnel, shared across the GG-Theory cohort and specialized here to the proton. Because no physical system is closed, the four-dimensional world every experiment reads is a boundary readout of a six-dimensional bulk; a readout that is the terminal basin of its stratum is not a free input but a determined one. The funnel is the same in every paper of the cohort and the third box is what changes: for GG-P3-Electron (Arisaka, 2026, P3-Electron) it is the electron, and for this paper it is the proton — its mass, its stability, its lifetime — read off one geometry, which is why every proton is identical to every other. The funnel states the shape of the argument, not its grade; the grades are the fences listed in this section and the ledger of Table 3.

F-P6-1 (the constitutional kill). A single observed proton decay, in any channel. Gauged $U(1)_B$ with the $\mathbb{Z}_3$-lock forbids $\Delta B = \pm 1$ to all orders; one event at Super-Kamiokande, Hyper-Kamiokande, DUNE, or JUNO falsifies the mechanism outright. This is the rare kill that grows *stronger* with every year of silence and is decidable on a stated timescale: the searches now in construction reach an order of magnitude beyond the current limit by ∼2040.

F-P6-2 (the fractional charge). A single confirmed free fractional charge — in a detector, in bulk matter, anywhere. The readout-locality reading of Q5 admits no exception.

F-P6-3 (the $\Delta B = 2$ door). An observed neutron–antineutron oscillation. The winding selection rule forbids $\Delta B = 2$ as absolutely as $\Delta B = 1$; an oscillation signal at ESS or in bound-neutron searches kills it.

F-P6-4 (the mirror). A measured proton–antiproton asymmetry — in $|q|/m$, magnetic moment magnitude, or mass — beyond the CPT-paired readout prediction. Current precision: 16 parts per trillion in charge-to-mass (Borchert et al., 2022).

F-P6-5 (the fifth force). A detected long-range force coupled to baryon number. The $U(1)_B$ of this framework is Stueckelberg-massive; its residual is exactly global. A baryonic fifth force at any range with gauge strength contradicts the mechanism. The experiment has existed longer than the theory: the equivalence-principle program has been, in effect, a search for exactly this force for over a century (Part VII).

F-P6-6 (the ledger). The registered kill criterion of the Arisaka equation, quoted at its home grade (Arisaka, 2026, A7-Qi4): a demonstrated boundary event that updates the baryonic ledger without the locked informational unit.

6 The cohort inheritance and the roadmap of the sixteen Parts

6.1 The cohort inheritance

GG-Theory is a twenty-two-paper research program (Arisaka, 2026, A1-Constitution) — eleven A-papers, six P-papers, three C-papers and two white papers — whose structural claim is that the observed laws are the boundary operational description of a real six-dimensional bulk — four macroscopic spacetime dimensions plus one scale direction I_r and one compact phase circle S^1_θ — governed by four axioms and an integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ (Arisaka, 2026, A3-BI6). Within that program this paper is a member of the Predictions Branch — the proton paper: the deployment of the derived machinery on the particle that carries almost all of the mass anyone has ever weighed, under the thesis that the proton is the ground attractor — the GGA — of the color-singlet baryonic stratum. Like every member paper of the cohort, it restates what it imports and owns what it proves, so that a reader who never opens a companion loses the provenance but not the argument.

Before the closest relatives, the family portrait. The reader new to the program should spend one minute with Figure 2, because the whole architecture can be read off it top to bottom, and every

Part of this paper will draw on some box of it. *One root:* the constitution GG-A1-Constitution states four axioms and seven postulates and proves nothing else — all force is downstream. *One bulk:* AX-2 compiles the root into the GG6 Trio — GG-A2-GG6 builds the six-dimensional geometry whose compact phase circle carries the winding that Part VI reads as baryon number, GG-A3-BI6 proves the anomaly cancellation that locks the sectors together and supplies the ledger with its single $\Delta B \in 3\mathbb{Z}$ door, and GG-A4-Euclid (Arisaka, 2026, A4-Euclid) tells the history. *One boundary law:* AX-3 forces GG-A5-GDOS — the open-system dynamics that Part III uses for the basin and its depth — organized by the two pillar papers GG-A6-GRIP (the geometric pillars: GFF, GRIP-In, the GGA — the method this paper runs end to end) and GG-A7-Qi4 (their quantum-information twins, which Part XI spends). *Three readouts:* GG-A8-QM (Arisaka, 2026, A8-QM) recovers textbook quantum mechanics, GG-A9-SM derives the Standard Model's 28 parameters — the codebook from which this paper's quark masses and α_s come — and GG-A10-Cosmos derives the cosmological inventory that Part X imports for the birth of baryons; GG-A11-Origin closes the series. *Two phenomenology branches:* everything below the capstone is phenomenology — falsifiable deployments of derived results, which is why their arrows are dashed. This paper sits in the cyan Predictions frame, fourth and last in its row, after the collider falsifier GG-P1-KK (Arisaka, 2026, P1-KK), the family-number derivation GG-P2-N3, and the sister paper GG-P3-Electron; the short dashed arrow that reaches this paper along that row, labeled GGA, is the one import that matters most — the sister paper supplies the method this paper runs. The teal frame carries the cosmology siblings, and each touches this paper at one place. Arisaka, 2026, C1-Kaxion is the cohort's other physical exploitation of the phase circle's topology — where this paper reads a winding of that circle as baryon number, the Kaxion reads an angle on it as dark matter, and the two are held by one ledger. Arisaka, 2026, C2-Hubble works the derived expansion history in which the baryon inventory of Part X has to land. And Arisaka, 2026, C3-BH owns the question this paper does not ask: what becomes of a globally conserved winding at a horizon. The reader who keeps this map in mind will never be lost: when Part III cites a theorem, it comes from the green or yellow boxes; when a number appears, it comes from GG-A9-SM; and when a fence is restated, it traveled here along one of the two dashed arrows into the cyan frame — to which the Inheritance Part (Part II) turns in detail.

The Foundations Branch. On the map's left flank stands its third frame — the Foundations Branch, a single column beside the spine, whose shared subject is the boundary's complex structure; its two members are recorded here at roster level, one sentence each. GG-P4-Real (Arisaka, 2026, P4-Real) derives the origin of the i that the whole quantum apparatus runs on — the gauge phase from the circle's quarter-turn, the state-space i from the causal clock — and the compact direction whose quarter-turn supplies that phase is the same direction whose winding this paper reads as baryon number. GG-P5-CPT (Arisaka, 2026, P5-CPT) gives the proton its twin: the antiproton as a receipt of that circle–clock handshake, with C, P, and T read as orientation reversals of the three real bulk factors — the identity that Part VI needs to close its dihedral structure, and the chain Part X imports for the matter excess. Both members carry P-series designators; their place at the spine's flank, not the phenomenology rows, marks their foundational role.

The twenty-two-paper map, identical in every paper of the cohort, is Figure 2, which closes this subsection.

6.2 Roadmap of the sixteen Parts

The paper walks its eleven questions in the order that lets each answer stand on the ones before it, and the walk is plotted in Figure 3. The present Part has put the questions and their century on the table, credited the standard account, fenced the central claim, and pre-registered the kills. Part II gathers the inheritance — the framework minimum, the Standard-Model derivation with its stability theorem as received, the $N = 3$ theorem, the mirror apparatus, the sister method, and the information pillars — so that every later import has its provenance stated once and its conditioning attached.

Part III is the center of gravity: the ground-attractor theorem — the unique deepest basin of the color-singlet baryonic stratum — answering the sharp mass (Q1) and the exact charge (Q2) as two faces of one fact, with the transmutation pricing of the mass and the embedding pricing of the charge. Five Parts read the same fact from five more sides, and one Part between them keeps the record. Part IV answers the spin (Q3): the readout label against the scheme-dependent bulk bookkeeping, with the Electron–Ion Collider face pre-registered. Part V takes confinement and the absent quark together (Q4, Q5): the cage measured and the mechanisms compared, the conditional area-law theorem T-P6-4 — one named hypothesis, the gap, from the full claim — the Goldstone-counting test, and the opening contract with the Clay problem. Part VI is the paper's own derivational core and its emotional one: the immortality and the law (Q6, Q7) — the obstruction theorem, the center identity, the $\mathbb{Z}_3$-lock that writes baryon number while breaking the symmetry and splitting the Higgs multiplet, the anomaly ledger with its single $\Delta B \in 3\mathbb{Z}$ door, and the Kamiokande arc from construction to theorem. Part VII then holds the physics still for one Part and keeps the record: the seventy-year history of the axiom Part VI has just discharged — from Lee and Yang's one-page Letter of 1955 to the imposition of March 2025 — kept apart from the derivations so that history and proof never borrow each other's authority. Part VIII reads the twin (Q8): the shallow basin, the 1.293 MeV competition, the gate-force descent, and the stabilizing bind. Part IX climbs the ladder (Q9): six flavors from $N = 3$, the excited tower, and the width-zero terminus.

Two Parts then face history and the ledger. Part X imports the birth of baryons (Q10) at its stated grade and proves the consistency sentence: the anomaly door that forbids one death permitted all births. Part XI states what $\mathrm{U}(1)_{Qi}$ means for the proton (Q11), at candidate grade, kill criterion first. Part XII weighs: significance, uniqueness against prior approaches, the falsification table, the open problems (the D-P6 registry), and the objections. Part XIII concludes: the century, the tank, and the theorem, in plain English. Part XIV is the workshop: the technical appendices, from the claim-status ledger to the complete derivations. Part XV answers the seventeen strongest objections, each at the register it deserves. Part XVI closes with the annotated references, every entry carrying its relevance note. Read in order, the sixteen Parts compose one argument; read by need, each names its imports and can stand a visit on its own.

The questions are on the table, the contracts are signed, and the map below shows the whole journey at a glance. One more Part of preparation — a walk through the toolshed — and the building begins.

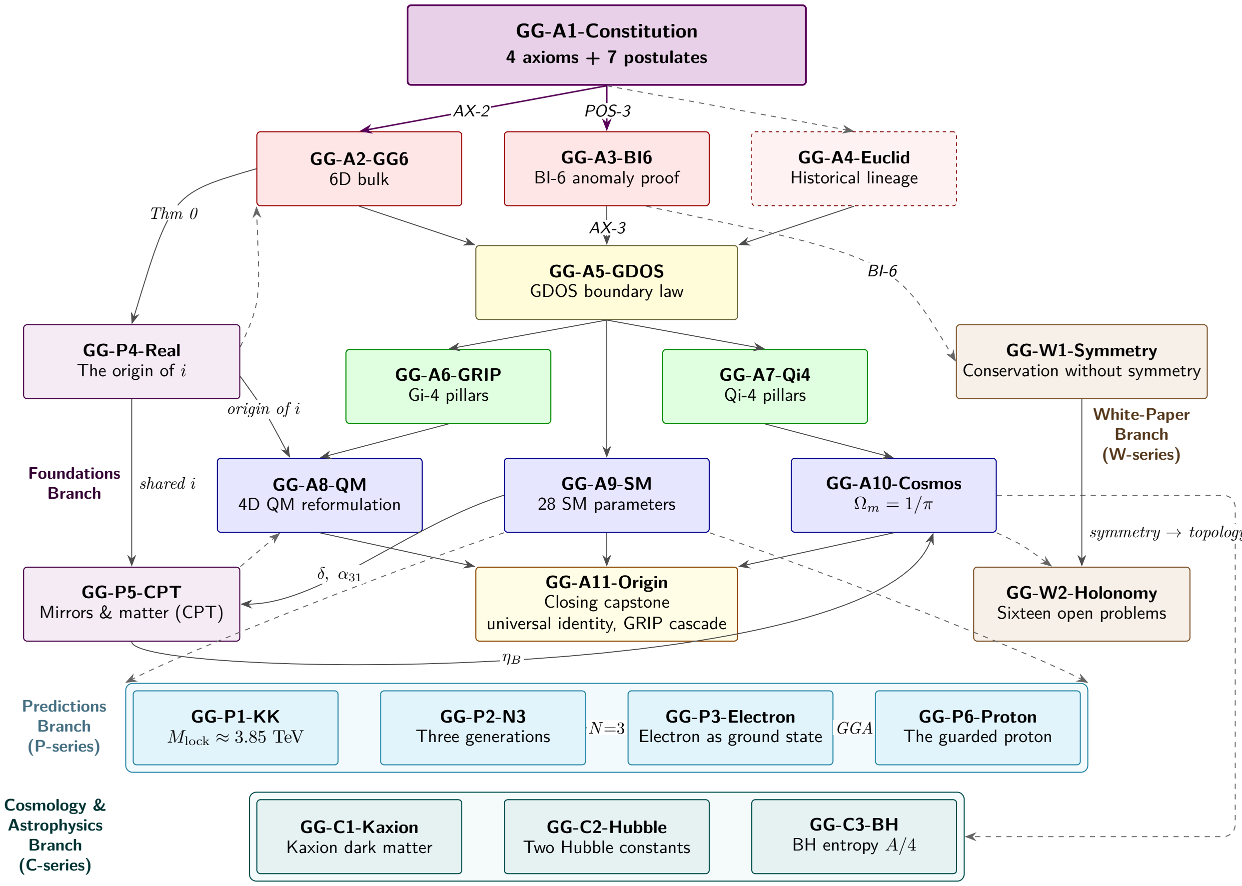


Figure 2: The twenty-two-paper cohort map of GG-Theory. The constitutional root GG-A1-Constitution (violet, top) supplies the four axioms and seven postulates from which the rest of the cohort descends: the GG6 Trio (GG-A2-GG6, GG-A3-BI6, GG-A4-Euclid, red) realizes the bulk geometry; GG-A5-GDOS (yellow) 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.

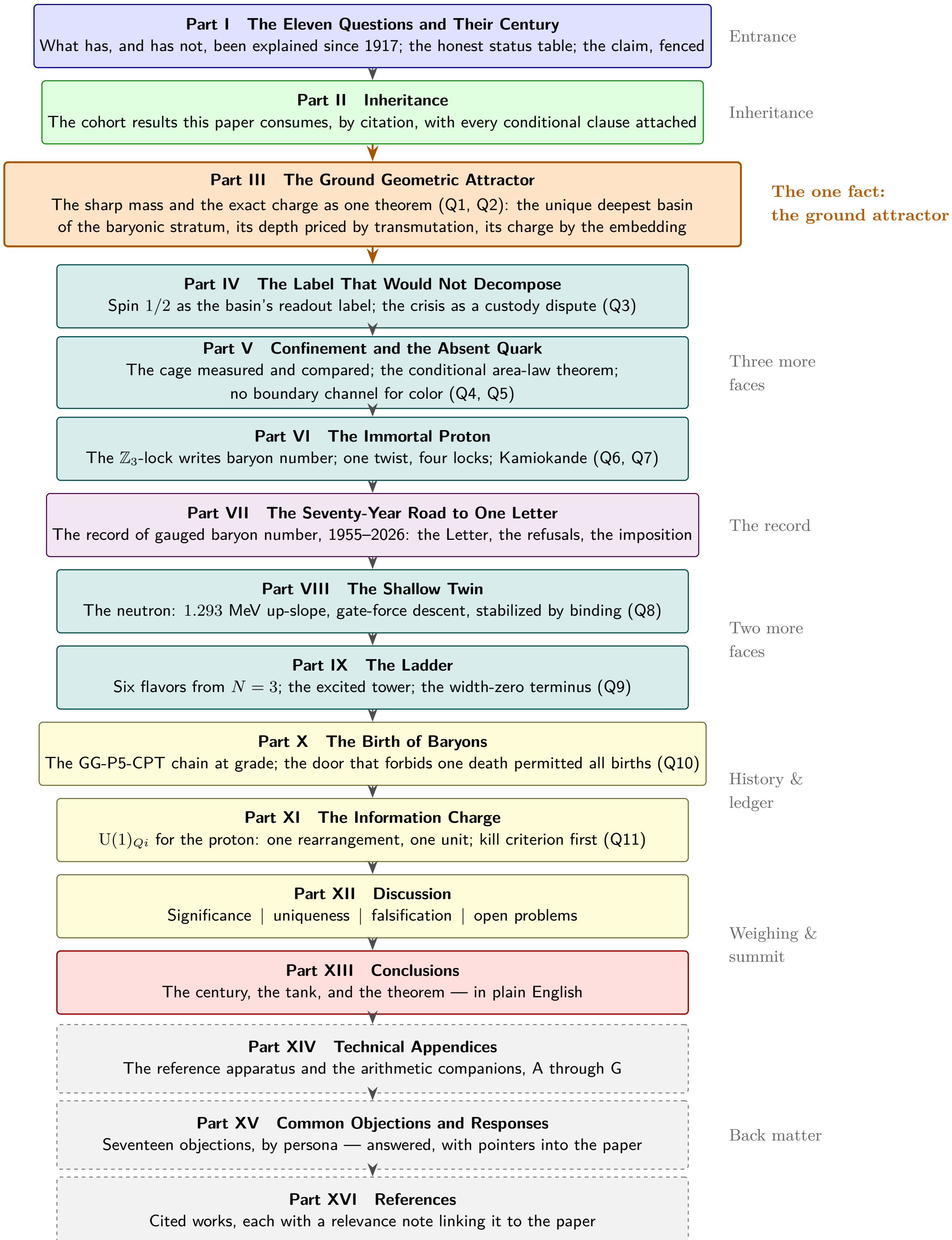


Figure 3: Roadmap of the sixteen Parts of GG-P6-Proton, in the nine phases walked in §6.2: the *entrance* (Part I), the *inheritance* (Part II), *the one fact* (Part III, highlighted), *three more faces* (Parts IV–VI), *the record* (Part VII), *two more faces* (Parts VIII–IX), *history and ledger* (Parts X–XI), *weighing and summit* (Parts XII–XIII), and the *back matter* (Parts XIV–XVI). Part III is highlighted because it carries the paper's central claim — the ground-attractor uniqueness of §4 — of which the answers of Parts IV–VI and VIII–IX are five further faces, and on which every later Part stands.

Part II
Inheritance

The cohort results this paper consumes, by citation, with every conditional clause attached

No result in this paper is proved twice. The framework it belongs to is a cohort of papers, each owning its own theorems, and the discipline that keeps such a program honest is performed here in the open: every result imported from elsewhere is declared once, with its source, its strength, and its conditions attached — the way a builder walks the site and inspects every delivered beam before construction begins. A reader eager for the physics may skim this Part on a first pass and return when a later chapter cites it; a reader auditing the paper will find here the complete list of what was assumed, what was proved elsewhere, and what this paper must build for itself.

7 How to read this Part

This paper stands on results proved elsewhere in the program, and the discipline of the Predictions Branch is that every import is declared once, here, with three things attached: its *home* (the paper that proves it), its *grade* (derived; derived conditionally, with the clauses named; interpretation; candidate), and its *consumer* (the Part of this paper that uses it). Nothing in Parts III–XI quietly assumes what this Part has not declared. A reader who accepts the imports at their stated grades can read the rest of this paper as self-contained; a reader who wishes to audit an import will find its full derivation at the cited home. The Part closes with the import ledger (Table 3), which is the contract in one page.

8 The runtime, in one picture: GRIP and the Ground Geometric Attractor

Everything this paper proves about the proton is one instance of a single mechanism, and the mechanism has a name the reader will meet on nearly every page that follows. It is worth learning once, slowly, here — because once it is in hand, the eleven questions of Part I stop being eleven puzzles and become eleven views of one object. The mechanism is GRIP, the runtime by which this framework's geometry settles into the stable things we observe, and its endpoint is the object this paper is about.

Start with the picture, in plain words. Deep in the six-dimensional geometry there is a fully symmetric starting configuration — every gauge equivalence intact, nothing yet committed, the theoretical equivalent of a ball balanced on the exact top of a dome. That symmetric top is unstable: the geometry carries a *free-energy landscape*, and a ball on a dome does not stay balanced. It rolls. As it rolls it *commits* — picks a direction, breaks the symmetry that held it at the top — and continues downhill, losing free energy at every step, until it reaches a valley it cannot leave. That final valley is the stable object. In the vocabulary of this program the four moves are named, and the reader should collect the names now, because the rest of the paper uses them as ordinary words:

- **DGI** (Dynamical Gauge Invariance) — the symmetric top: the fully gauge-invariant configuration from which the descent begins, every equivalence still unbroken.
- $\mathcal{F}_{\mathsf{GFF}}$ (the Geometric Free-energy Functional) — the landscape itself: the height function whose valleys are the stable configurations and whose ridges are the barriers between them. The descent obeys $d\mathcal{F}_{\mathsf{GFF}}/dt \leq 0$ — downhill, always, the open-system analogue of the second law.
- **GSSB** (Geometric Spontaneous Symmetry Breaking) — the commitment: at each saddle of the landscape the system selects one branch, paying a definite topological toll to cross, and the symmetry that offered the choice is broken by the choosing.
- **GA** and **GGA** (Geometric Attractor; Ground Geometric Attractor) — the valley: a stable resting place. There are two grades of valley, and the difference between them is the whole subject of this paper.

Compactly, the runtime is the chain

$$\mathsf{GRIP} \;:=\; \mathsf{DGI} \;\to\; (\mathcal{F}_{\mathsf{GFF}}) \;\to\; \mathsf{GSSB} \;\to\; \mathsf{GGA}, \tag{1}$$

Two words in that chain do the most work in this paper and are easiest to conflate, so Figure 4 separates them: GRIP-In, the descent that brings a configuration to rest, and GRIP-Out, the ascent that builds the next level of structure on a basin already at rest. Every Part of this paper is one or the other, and no Part is both.
read left to right as *free symmetric top → landscape → commitment → unique ground state*. It is proved, as a runtime with the stated descent and halting properties, in the program's dedicated paper GG-A6-GRIP (Arisaka, 2026, A6-GRIP), from which this paper inherits it whole.

The two grades of valley — the distinction that makes a proton. A landscape has many valleys, and they are not all alike. Most are stable only in the mild sense that a small nudge rolls back: displace the ball a little and it returns to the valley floor. Such a valley is a GA, a Geometric Attractor — *a* stable configuration, but not necessarily *the* stablest, because somewhere else on the landscape there may be a deeper valley, and a large enough disturbance — or, in quantum mechanics, a patient enough wait for tunneling — will eventually carry the system there. A muon is a GA in this sense: perfectly well-defined, but with a deeper valley (the electron) reachable through a gate, so it lasts 2.2 microseconds and is gone. An excited atom is a GA: it will relax. A radioactive nucleus is a GA: it will decay. These are way stations, not destinations.
The other grade is the destination. A GGA, a *Ground* Geometric Attractor, is the valley that is *globally* deepest on its landscape — and, crucially, is also admissible under the framework's four consistency pillars (the Qi-4 conditions of GG-A7-Qi4, which guarantee the state is a legitimate

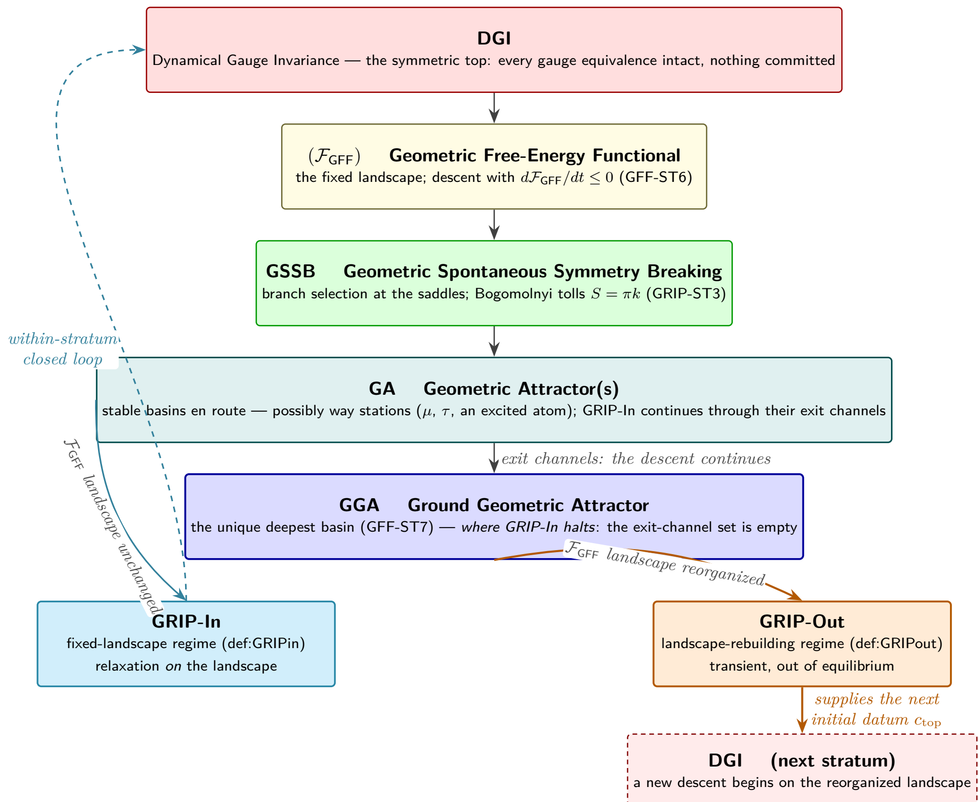


Figure 4: The GRIP cascade and its two regimes, in one picture, adapted from GG-A6-GRIP (Arisaka, 2026, A6-GRIP); the full eighteen-rung deployment is GG-A11-Origin's (Arisaka, 2026, A11-Origin). The same machinery runs in two directions and this paper uses both, so the distinction is worth a drawing rather than a definition. GRIP-In is the descent: a configuration rolls down the free-energy landscape, commits at each saddle, and comes to rest — it is how the proton reaches its basin and how an excited baryon falls to it. GRIP-Out is the ascent: a settled basin becomes the substrate on which the next level of structure is built — proton and electron to hydrogen, and hydrogen upward. Nothing is reversed between them; the descent has no inverse, and the ascent is a different move on a different stratum, which is the whole content of the Chain of Figure 6.

quantum readout and not a mathematical artifact). At a GGA there is nowhere deeper to go. No nudge, no wait, no tunneling event can find a lower valley, because there isn't one. This is stability of an entirely different character from a GA's: not stability against small perturbations, but stability against *everything the landscape allows* — including the slow, inexorable quantum tunneling that eventually empties every merely-local minimum. In one line: *a GA is stable against a push; a GGA is stable against eternity.*

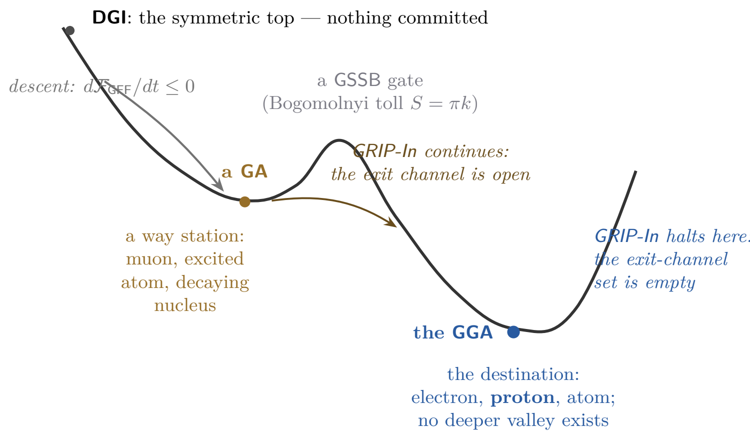


Figure 5: The runtime (1) as one landscape. From the symmetric top (DGI) the configuration rolls down the free-energy landscape $\mathcal{F}_{\mathsf{GFF}}$, committing at each GSSB gate. It can be captured in a way-station valley — a Geometric Attractor (GA: a muon, an excited atom, a radioactive nucleus) — from which an open exit channel still leads downhill, so the descent (GRIP-In) continues. It halts only at the globally deepest admissible valley, the Ground Geometric Attractor (GGA): the electron, the *proton*, the atom — the stable things the world is built from. A GA is stable against a perturbation; only a GGA is stable against tunneling, because on its stratum there is no deeper valley to tunnel to. This paper proves that the proton is a GGA.

This distinction is not a technicality; it is the reason chemistry exists. Chemistry made exactly this distinction a century ago without naming it. A molecule's electrons have many stationary arrangements, but chemistry is built on the *ground state*: every water molecule is identical, and indefinitely stable, precisely because its electrons occupy not merely *a* stable arrangement but *the* lowest one. The Rydberg constant is a property of *the* hydrogen ground state, not an average over a population of excited states that might drift. The GGA is that everyday idea — "the ground state is what lasts and what is reproducible" — promoted to a constitutional principle of the framework's runtime. When this paper says the proton is exactly reproducible to twenty-one digits across the whole universe (Q2), it is saying the proton is a GGA, and reproducibility is what GGA-hood means.

The two regimes: GRIP-In and GRIP-Out. One more pair of names, and the vocabulary is complete. The descent just described — rolling down a *fixed* landscape until it halts at the GGA — is called GRIP-In, the in-flow regime. It is the regime this paper uses in Part VIII to price the neutron's β-decay, exactly as the sister paper GG-P3-Electron used it to price the muon's: a GA draining through its one open gate toward the GGA below it. But a landscape can also *change*. A transient, out-of-equilibrium event can reorganize $\mathcal{F}_{\mathsf{GFF}}$ itself — open valleys that did not exist before, close others — and thereby hand the next GRIP-In descent a new starting point. That landscape-reorganizing regime is called GRIP-Out. The one-sentence division, from GG-A6-GRIP: *GRIP-Out opens the landscape; GRIP-In finishes the journey.* The cosmic cooling that froze the electroweak vacuum was a GRIP-Out event; every weak decay since has been GRIP-In on the landscape that event left behind. We will need both regimes in the next section, because the proton's deepest significance is not that it is one GGA, but that it is a GGA on which a whole *sequence* of GRIP-Out events built everything else.

9 The Chain of GRIP-Out: where the proton sits

Here is the grand picture, and it is the reason a paper about a single particle claims to touch the heart of the whole framework. The runtime of the previous section does not run once. It runs again and again, up a ladder, each rung standing on the one below it — and the proton is one of the lowest rungs, the ground on which nearly everything else is built.

The pattern is an alternation. GRIP-In settles the system into the GGA of its current landscape; that settled GGA then becomes the *substrate* on which a GRIP-Out event can act, reorganizing the landscape and opening a new stratum with new valleys; GRIP-In descends again to the new GGA; and the cycle repeats. The capstone paper GG-A11-Origin (Arisaka, 2026, A11-Origin) proves that this alternation, given the framework's fixed geometry, runs as a single determined cascade from the elementary particles all the way to conscious observers — and that at every rung the outcome is a *unique* GGA, so the whole ladder is forced, not lucky. Schematically,

$$\mathcal{C} \xrightarrow{\mathsf{GRIP}} \mathsf{GGA}_1 \xrightarrow{\mathsf{GRIP\text{-}Out}} \mathsf{GGA}_2 \xrightarrow{\mathsf{GRIP\text{-}Out}} \cdots \xrightarrow{\mathsf{GRIP\text{-}Out}} \mathsf{GGA}_{18}, \tag{2}$$

the *Chain of GRIP-Out*: each GGA_n the settled ground state of its stratum, each arrow a landscape-reorganizing event supplied — from the second rung onward — by the dynamics of the rungs already built. The reader coming to this framework for the first time should pause on what (2) claims: that the same four-move engine that selects a quark's properties also selects an amino acid, a genetic code, and the length of a conscious moment — one mechanism, run at higher and higher rungs, with no new assumption added for chemistry, life, or mind. That claim is GG-A11-Origin's to defend, and this paper imports it at GG-A11-Origin's grade; what matters *here* is where the proton sits on the ladder, and what stands on it.

The proton sits near the very bottom, on the *baryonic stratum*: the family of color-singlet, three-quark configurations carrying baryon number one. Its GGA — the globally deepest admissible valley of that stratum — is the proton. And here the picture turns, and turns in the direction that gives this paper its title as a message to experimentalists. It is natural to think of the proton, as Part III invites one to, as an *endpoint*: the bottom of the baryonic descent, the place with no exit gate, the terminus. That is true, and it is half the story — the downward-looking half. The half that matters for why the proton is "the heart of the theory" is the *upward*-looking one. Because the proton is an absolutely stable GGA, it can serve as the substrate for the next GRIP-Out event: cooling lets electrons fall onto nuclei built from protons, and the atomic stratum opens (the periodic table, $\mathsf{GGA}_{\text{atomic}}$ at the Rydberg scale); chemistry lets atoms bond, and the molecular stratum opens; and

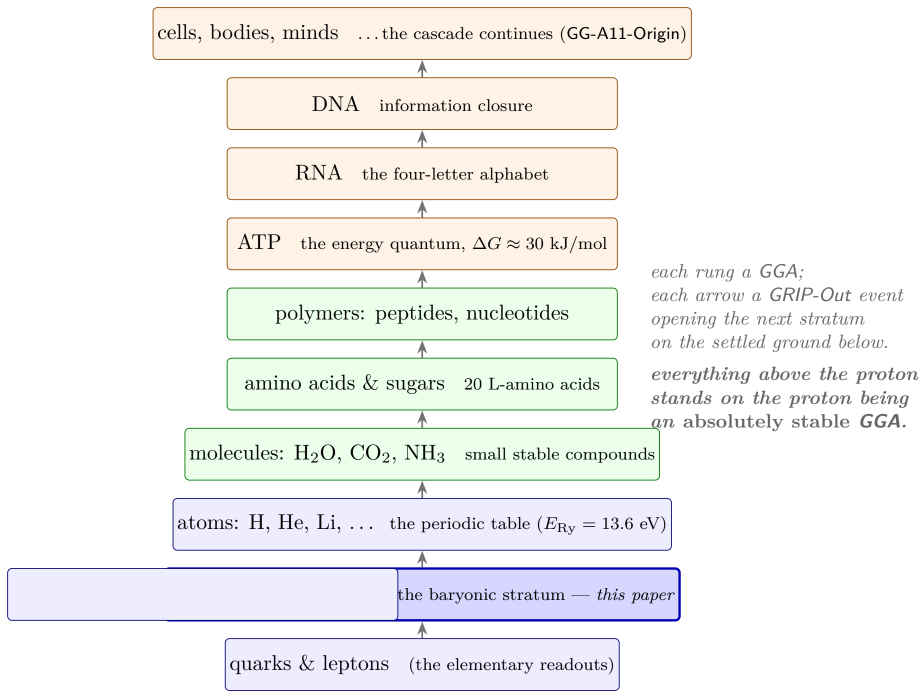


Figure 6: The Chain of GRIP-Out (2), drawn for the matter rungs (the full eighteen-rung cascade to mind is GG-A11-Origin's (Arisaka, 2026, A11-Origin)). Each rung is the Ground Geometric Attractor of its stratum; each upward arrow is a GRIP-Out event that reorganizes the landscape and opens the next stratum on the settled ground below it. The proton (highlighted) is the GGA of the baryonic stratum, and it is load-bearing in the most literal sense: atoms need a stable proton to have a nucleus; molecules need atoms; amino acids, proteins, ATP, RNA, and DNA each need the rung beneath them. Remove the proton's absolute stability and the chain has no ground — the periodic table and everything above it never forms. This paper is the study of that ground rung.

so on up through amino acids, proteins, ATP, RNA, DNA, and every rung above. *Every stable object more complex than a bare particle stands, ultimately, on the proton holding still forever.* A proton that decayed — even slowly — would be a ground that crumbles, and the whole tower built on it would have a finite shelf life. That the tower does *not* have a shelf life, that matter is permanent enough to build a chemist who can ask why, is a statement about the proton being a GGA, and it is the statement this paper exists to prove.

Physics intuition: the foundation stone. A cathedral's foundation stone is not its most spectacular feature — no one visits to admire it — but every arch, vault, and spire transmits its load to that stone, and if it shifts, everything above it moves. The proton is the foundation stone of the material world. The excited baryons and the free neutron above it are scaffolding that comes and goes (Part IX's tower, Part VIII's twin); the atoms, molecules, and living machinery above *it* are the cathedral. The century asked what the proton is made of and answered in exquisite detail (Part III's mass review). This framework asks a different question — what *kind* of thing the proton is, that it can hold the weight of chemistry forever — and answers: it is the Ground Geometric Attractor of the baryonic stratum, the foundation stone at the bottom of the Chain of GRIP-Out.

10 Two grounds, one grammar: the proton and the electron

One comparison locates this paper in the cohort more precisely than any other, and it is worth making explicitly, because it is the comparison that shows the proton's account is not improvised for this paper but is a second instance of a template the program has already run. The template is: *an absolutely stable particle is the Ground Geometric Attractor of its stratum, and all its mysteries are corollaries of that one fact.* The sister paper GG-P3-Electron (Arisaka, 2026, P3-Electron) runs the template for the electron; this paper runs it for the proton. Side by side:

The parallel is exact except in one place, and the exception is the whole physics of this paper. For the electron, "no deeper valley" is a statement about a Morse landscape: the charged-lepton stratum simply has no basin below the electron's, and GRIP-In halts because there is nowhere to go. For the proton, "no deeper valley" has to be made *exact* against a subtle threat — the grand-unified operators that would connect the proton to a deeper, baryon-number-violating valley (a positron plus a pion, say). What removes those operators, and so guarantees the baryonic GGA is a true ground and not merely a very deep GA, is the gauging of baryon number and the $\mathbb{Z}_3$-locked winding of Part VI. In the language of this section: *Part VI is the proof that the proton is a GGA rather than a GA* — the proof that its exit-channel set is not merely small but exactly empty. The electron gets its GGA-hood from the shape of its landscape; the proton earns its GGA-hood from a gauged topological law. Same grammar, one stratum over, with the deepest clause promoted from geometry to gauge symmetry.

This is why the two papers are twins and why P6 belongs beside P3 on the shelf. Between them they establish the two GGAs from which all ordinary matter is assembled: the electron on the leptonic stratum, the proton on the baryonic one. Bind one electron to one proton and the atomic stratum opens — hydrogen, the first rung above the particles in the Chain of GRIP-Out. Everything else is

Table 2: The electron and the proton, question by question. Each row asks one question of both particles and sets the two answers side by side: which stratum each is the ground attractor of, what the single governing fact is, why every readout of either is exactly reproducible, and why neither can decay. The parallel is the point — the two papers are one argument run twice, once on the charged-lepton stratum and once on the baryonic one.

	Electron (GG-P3-Electron)	**Proton (this paper)**
The stratum	the charged-lepton stratum	the baryonic stratum $(B, Q, J) = (1, +1, \frac{1}{2})$
The one fact	the electron is the GGA of that stratum	the proton is the GGA of that stratum
Why exactly reproducible	every readout is the same ground basin — GGA universality	every readout is the same ground basin — GGA universality
Why it cannot decay	no deeper charged-lepton valley; GRIP-In halts	no deeper $B = 1$ valley; gauged winding removes every operator to a deeper one (Part VI)
The way stations	the muon and tau: GAs of the same landscape	the excited baryons and the free neutron: GAs of the same landscape
The twin	the positron: conjugate readout of the same basin (GG-P5-CPT)	the antiproton: conjugate readout of the same basin (Part VI)

chemistry.

And one grammar more: what kind of protection each enjoys. The template above says both particles are ground attractors. It is worth adding what protects each *once it has landed*, because the two answers differ, and the difference is the sharpest available statement of what this paper claims. The electron's stability is the absence of a deeper valley: nothing on its stratum lies below it, and the descent has no inverse, so it stays. The proton's stability is of a stronger kind. Its baryon number is a *winding* of the compact geometry — an integer — and an integer is not protected by the absence of a lower state but by the impossibility of continuous motion: nothing continuous acts on $\mathbb{Z}$. That is the top rung of the companion review's ladder, *protection without symmetry* (Arisaka, 2026, W1-Symmetry): a symmetry can be broken, and every symmetry-based proton-stability argument of the last fifty years was broken on purpose by the theory that proposed it. A winding has nothing to break.

The contrast worth carrying away is with the electroweak sector, which lives on the same circle and is protected far more weakly. The Higgs is also circle-side, but it is a *continuous* modulus — a Wilson-line angle, not a winding number — so it moves, and every quantity built from it runs (Arisaka, 2026, A9-SM). What non-locality buys there is finiteness, not fixity. Baryon number is the other case: not a modulus but a class, not finite but frozen. Both facts are consequences of the same sentence — holonomy requires closed loops, and an interval has none (Arisaka, 2026, W2-Holonomy) — and the two readings of it are why the electroweak scale is calculable while the proton is immortal.

And the one axis on which they are opposite. The rows above are parallels; there is one axis on which the two particles are not parallel but opposite, and it is worth naming because a reader who noticed it and was not told would be right to suspect the template of being elastic. The electron has no inside. GG-P3-Electron (Arisaka, 2026, P3-Electron) carries that as a theorem rather than as a bound — the structural form factor is identically unity at every momentum transfer however large, every structural radius moment vanishes exactly, and the paper pre-registers the sharpest version of the claim it can: no substructure will ever be found, at any spatial scale, by any probe, at any energy. The proton has an inside, and had one before anyone could say what an inside would mean; this paper's own historical Part dates the discovery to 1933 and prices the interior at $\langle r^2\rangle^{1/2} \approx 0.84$ fm. Figure 7 puts the two on one axis: the electron's flat line at $F \equiv 1$, the proton's falling curve, and — for contrast — the curve a composite electron would trace, falling at whatever scale its compositeness lived at.

So the two grounds are exact for opposite reasons, and this is the sharpest way to say what a Ground Geometric Attractor is. The electron is exactly reproducible because there is nothing inside it to vary. The proton is exactly reproducible although there is a great deal inside it to vary: a storm of gluon field energy, sea pairs and quark kinetic energy that Part III prices at nearly the whole 938.272 MeV, none of it fixed, all of it in motion. What is fixed is not the contents but the basin. Every proton is the same readout of the same terminal valley, so every proton weighs the same to the last measured digit while no two of them contain the same configuration for two consecutive instants. An attractor does not need its interior to be still. It needs its interior to have nowhere else to go.

That is also the honest place to say what this paper does *not* inherit. The pointlikeness theorem is GG-P3-Electron's and stays there: nothing in the present paper derives it, depends on it, or would be damaged if it failed. It is carried here as the contrast case, because the contrast is what makes the shared grammar legible — and because a framework that produced exactness by one route only would be a weaker thing than one that produces it by two.

11 The framework minimum

Five structures constitute the minimum this paper needs from the foundational branch; they are stated here in the form in which they are used.

The bulk and the boundary. Spacetime as experienced is the four-dimensional boundary readout of a six-dimensional bulk $\mathcal{M}_6 = M_4 \times I_r \times S^1_\theta$: a radial direction r (scale; an interval) and a compact cycle θ (phase; a circle), neither spatial. Depth along the interval is measured in e-folds down from the geometric seam, $r = \ln(E_{\text{seam}}/\mu)$ with $E_{\text{seam}} = M_{\text{Pl}}/2$; every depth quoted in this paper is measured from there. One register note, because the cohort uses the neighboring symbol for a different scale: the grand-unified edge written $E_{\text{GUT}} = M_{\text{Pl}}e^{-2\pi} = 2.28 \times 10^{16}$ GeV elsewhere in the program sits $2\pi - \ln 2 = 5.6$ e-folds below the seam, at $r = 5.6$ on this paper's axis, and is not this paper's origin. The constitutional axioms — locality–causality, a single variational principle, the minimal-structure clause — are those of GG-A1-Constitution (Arisaka, 2026, A1-Constitution),

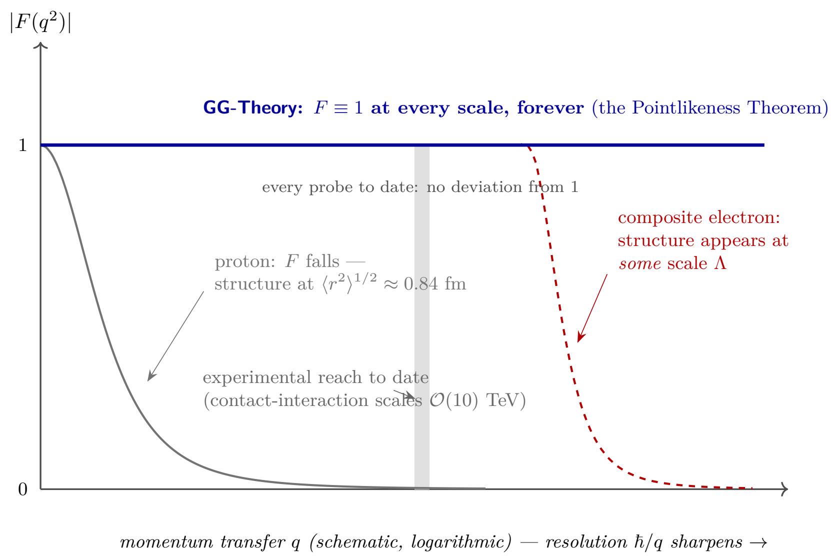


Figure 7: The one axis on which the two ground attractors are opposite. The horizontal axis is momentum transfer, so moving right is resolving finer; the vertical axis is the structural form factor. The proton's curve falls, and where it falls says how big the inside is — $\langle r^2\rangle^{1/2} \approx 0.84$ fm, a number Part I dates to 1933 and Part III spends in full. The electron's line does not fall: GG-P3-Electron (Arisaka, 2026, P3-Electron) carries $F \equiv 1$ as a theorem at every momentum transfer however large, not as a bound awaiting improvement, and the dashed curve shows what a composite electron would have to do instead — fall somewhere, at some scale, which every compositeness model owes and none has ever delivered. The figure is imported as the contrast case and nothing in this paper rests on it: the electron's exactness comes from having no interior, the proton's from having an interior with nowhere to go, and the two together are what a Ground Geometric Attractor means.

realized as geometry in GG-A2-GG6 (Arisaka, 2026, A2-GG6). Everything in this paper happens on that boundary or descends to it.

The open-system law. The boundary is not a closed system: what appears on it is governed by the projection dynamics of GDOS (Arisaka, 2026, A5-GDOS), whose tower theorem (T-GDOS-9.1) supplies the mode expansion this paper's Part VI reads: every bulk field is a tower over the compact directions, the light floor of the tower is what the boundary sees, and the massive floors cluster at the lock scale $M_{\text{lock}} \approx 3.85$ TeV.

Attractors and their readout. The boundary's stable objects are the Ground Geometric Attractors (GGA) of their strata — the concept developed at length in §§8–10 above — organized by the free-energy functional GFF and reached by the descent machinery of GG-A6-GRIP (Arisaka, 2026, A6-GRIP). The in-flow reading (GRIP-In) prices the descent of any non-ground configuration — the apparatus this paper uses for the neutron's β-decay in Part VIII exactly as the sister paper used it for the muon.

The selection principle. Where a symmetric structure offers branches, the runtime selects the stable attractor branch: geometric spontaneous symmetry breaking (GSSB), also from GG-A6-GRIP. Part V's reading of confinement — the color-singlet branch as the unique stable attractor in strong coupling — is a GSSB statement inherited from the Standard-Model paper's GRIP chapter and engaged at its stated grade there.

The anomaly bookkeeping. The modified Bianchi identity of GG-A3-BI6 (Arisaka, 2026, A3-BI6) supplies the Green–Schwarz inflow that Part VI's anomaly ledger charges its two non-vanishing coefficients against. This paper does not re-derive that bookkeeping; it consumes it as hypothesis H3 of the stability theorem, exactly as its home paper states it.

12 The gauge inheritance: GG-A9-SM

The largest single inheritance is the Standard-Model derivation of GG-A9-SM (Arisaka, 2026, A9-SM), from which this paper takes five results verbatim.

The bulk gauge group. The unified bulk group is

$$\mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi} \times \text{Gravity}, \tag{3}$$

with the two Abelian factors *local* in the bulk — the constitutional fact from which this paper's Q7 begins. Each Abelian factor is *imposed* as a local gauge invariance, in deliberate analogy with electromagnetism; the imposition of $\mathrm{U}(1)_B$ is the framework's founding act, and its record — external and internal — is kept in Part VII. The visible descent is

$$\mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi} \xrightarrow[\text{boundary conditions + holonomy}]{} \mathrm{SU}(3)_C \times \mathrm{SU}(2)_L \times \mathrm{U}(1)_Y, \tag{4}$$

with hypercharge fixed inside SU(5) (hence charge quantization) and the electroweak stage completing to $U(1)_{EM}$ as in the home paper.

The matter packets. Each family is one bulk spinor packet whose chiral zero modes arrive in the complete $\overline{\mathbf{5}} \oplus \mathbf{10}$ pattern — fifteen left-handed Weyl fields per family, forty-five in all; the interval boundary condition projects the chirality, and the gauge anomalies cancel packet by packet as a bookkeeping identity. Baryon-number assignments on the split spectrum,

$$B(Q) = +\tfrac{1}{3}, \qquad B(u^c) = B(d^c) = -\tfrac{1}{3}, \qquad B(L) = B(e^c) = 0, \tag{5}$$

are forced by the constitutional locality of $U(1)_B$. The parity assignment of the descent, derived at the GG-A5-GDOS level and used by GG-A9-SM,

$$P = \mathrm{diag}(+1, +1, +1, -1, -1), \tag{6}$$

is the object whose conjugation action Part VI examines with care — the single most load-bearing inheritance in this paper.

The stability theorem, as received. GG-A9-SM proves (its T-SM-60.1): *assuming* (H1) the X, Y bosons of the adjoint are bulk-only, absent from the boundary spectrum; (H2) the bulk $U(1)_B$ descends to act on the split fields as baryon number itself; and (H3) the $U(1)_B$ gauge anomalies are canceled by the BI-6 Green–Schwarz inflow — then every local operator with $\Delta B = \pm 1$ or ± 2 is forbidden to all orders, and the only admissible violation is the $SU(2)_L$ anomaly, $\Delta B = 3n$, exponentially closed at zero temperature. At its home, (H2) was the one load-bearing hypothesis still to be discharged, deferred to a dedicated successor paper on proton decay — *this* paper. Part VI is that discharge: the obstruction theorem that makes (H2) impossible for any Lie-algebra charge, and the $\mathbb{Z}_3$-locked descent that realizes it as a winding, with (H1) emerging as a corollary. The protective symmetry throughout is the *global* baryon number residual to a Stueckelberg-massive $U(1)_B$ — no long-range fifth force accompanies it, which is itself falsifier F-P6-5.

The strong scale. The mass pricing this paper uses in Part III is GG-A9-SM's: the derived gauge couplings run by radial transport; Λ_{QCD} emerges by dimensional transmutation from the derived g_3; and the resulting division of the proton's mass — the strong interaction's own scale paying $\sim 99\%$, the Higgs-coupled quark masses the remaining percent — is inherited with its home paper's honesty note: the transmutation mechanism is standard physics (Wilson, 1974); what the framework adds is the derivation of the coupling it starts from.

The basin/gate architecture. GG-A9-SM divides the forces by structural role: unbroken long-range forces are *basins*; the broken, short-range weak force is the *gate* — the unique channel through which descents between basins run. Part VIII uses this verbatim: the neutron's β-decay is a gate transit, not an anomaly of the strong sector.

13 The family inheritance: GG-P2-N3

The family count is the two-sided theorem of GG-P2-N3 (Arisaka, 2026, P2-N3): $N \geq 3$ from the requirement of a physical CP phase (the MSMF lower bound), $N \leq 3$ from the capacity theorem T-N3-6 — the family stratum funds exactly π of relaxation budget per family, derived from its own quantum geometry (Berry transport at the Born theorem's grade), against Bogomolnyi tolls that grow as the triangle number — hence $N = 3$, carried at the home paper's "derived (conditional)" register, the conditioning being its coupling clause with the integrality lemma L-INT, stated there. Six quark flavors follow by counting: each family carries one up-type and one down-type flavor, so three families give exactly

$$(u, d), \quad (c, s), \quad (t, b), \tag{7}$$

and the "six" of Q9 is not a separate mystery but the doubled family count. Part IX consumes this, together with the excited spectrum machinery of the framework minimum, for the ladder.

14 The mirror inheritance: GG-P5-CPT

From the CPT companion (Arisaka, 2026, P5-CPT) this paper takes two distinct inheritances, one algebraic and one cosmological, and it is scrupulous about their different grades.

At theorem grade: the twin and the reversal. The origin of antiparticles is imported as proved structure: the circle carries conjugation as orientation reversal ($\theta \to -\theta$; T-P5-A), the clock structure pairs it (T-P5-B), the handshake fixes the Feynman–Stückelberg pairing as the unique consistent reading (T-P5-C), and the fermionic factorization makes the charge flip definitional (T-P5-C2). Two Parts consume this: Part VI, where the reversal-is-conjugation identity turns out to be precisely the closure condition of the dihedral structure that writes baryon number — the deepest single point of contact between the two papers — and the falsifier face F-P6-4, where the antiproton's measured equalities (Borchert et al., 2022) test the conjugate-readout reading of the antiproton exactly as the positron tested the electron's in the sister paper.

At conditional grade: the birth chain. GG-P5-CPT's account of the baryon asymmetry — resonant TeV-scale leptogenesis (Fukugita and Yanagida, 1986) with the resonance condition as its one named input, the sphaleron-transport normalization as its one named conjecture (C-P5-C), and the yield η_B delivered to the cosmology paper (Arisaka, 2026, A10-Cosmos) — is imported at exactly that declared grade, nothing upgraded. Part X adds only the consistency sentence this paper is uniquely positioned to prove: the chain's sphaleron step passes through the $\Delta B \in 3\mathbb{Z}$ anomaly door, which is the one door Part VI's selection rule leaves open ('t Hooft, 1976). The mechanism that made the baryons and the mechanism that preserves them are the same equation read at two temperatures.

15 The method inheritance: GG-P3-Electron

The sister paper (Arisaka, 2026, P3-Electron) supplies the method this paper walks: state the questions at their sharpest; credit the standard account in an honest status table; prove the ground-state uniqueness of the stratum; read every remaining question as a face of it; fence what is conditional; register what is owed; and pre-register the kills. It also supplies a worked example this paper leans on directly: the positron as the *conjugate readout of the same basin* — one object, two orientations of reading it — which Part VI generalizes from the electron's basin to the baryonic winding (the antiproton as the reversed wrap), and which the dihedral structure of the $\mathbb{Z}_3$-lock echoes at the level of the compact geometry itself. Where the electron's stability was the absence of an exit gate from a basin, the proton's will be the absence of an operator that can unwind a winding: the two stability theorems are siblings, and Part VI states the family resemblance precisely.

16 The information inheritance: GG-A7-Qi4

From the quantum-information pillars (Arisaka, 2026, A7-Qi4) this paper takes, at that paper's own candidate grade and with its kill criterion quoted intact, the Arisaka equation: at every elementary boundary event the energetic, electric, baryonic, and informational currents are locked,

$$J_E/\mathsf{Q}_\mathsf{B} \;=\; J_e \;=\; J_B \;=\; J_{Qi}, \qquad \mathsf{Q}_\mathsf{B} \;=\; \frac{2}{5}\,\frac{E_{\text{Ryd}}}{K} \;\approx\; 0.1555\ \text{eV}, \tag{8}$$

with $K = 35$ the ledger constant of the cohort. Part XI's task is strictly bounded: to state what this locking means for the proton — one baryonic rearrangement, one informational elementary update, priced at Q_B — and what would kill it (F-P6-6), without promoting the grade its home paper declares.

17 The import ledger

The ledger's one-sentence summary, for the reader keeping score: this paper's genuinely new claims live in Parts III–VI, and everything they stand on is either derived at home or fenced by name here; nothing arrives unlabeled.

The supply lines are laid and inspected. From here the paper builds. The next Part erects the central claim — the proton as the Ground Geometric Attractor of its stratum — and every Part after it reads that one structure from another side. The reader who skimmed is released to the physics; the reader who audited now knows exactly what the physics will be allowed to use.

Table 3: The import ledger: every result this paper consumes, its home, its grade as declared at home, and the Part that consumes it. Grades: **D** derived; **D(c)** derived conditionally (clauses stated at home and where used); **INT** interpretation, named; **CAND** candidate, kill criterion registered.

Import	Home	Grade	Consumed by
Bulk, boundary, axioms; realization as geometry	GG-A1-Constitution; GG-A2-GG6	D	everywhere
GDOS projection; tower theorem T-GDOS-9.1; M_{lock}	GG-A5-GDOS	D	III (floors), VI (winding floors)
GGA/GFF/GSSB/GRIP-In attractor machinery	GG-A6-GRIP	D	III, V, VII
Green–Schwarz inflow (BI-6)	GG-A3-BI6	D	VI (as H3, verbatim)
Bulk group (3); descent (4); packets; B-assignments (5); parity (6)	GG-A9-SM (GG-A5-GDOS)	D(c)	VI (core), III (charge)
Stability theorem T-SM-60.1 as received (H1–H3)	GG-A9-SM	D(c)	VI (completed there)
Derived couplings; Λ_{QCD} by transmutation; basin/gate architecture	GG-A9-SM	D(c)	III (mass), VII (gate)
$N = 3$ two-sided theorem; six flavors by doubling	GG-P2-N3	D(c)	VIII
Antiparticles: T-P5-A/B/C/C2 (reversal = conjugation; pairing; charge flip definitional)	GG-P5-CPT	D	VI (closure condition), F-P6-4
Leptogenesis chain; C-P5-C; η_B to cosmology	GG-P5-CPT; GG-A10-Cosmos	D(c)	IX (at grade)
Ground-state method; conjugate readout worked example	GG-P3-Electron	D	method throughout; VI
Arisaka equation (8); $\mathsf{Q_B}$; kill criterion	GG-A7-Qi4	CAND	X (at grade), F-P6-6
Pointlikeness $F \equiv 1$ and its falsification interface, imported as the contrast case only	GG-P3-Electron	D	II (§10), nowhere load-bearing
Holonomy primer: loop phase, Wilson loop, and the semigroup arrow	GG-W2-Holonomy	INT	VI (§55)

Part III
The Ground Geometric Attractor

The proton as the GGA of the baryonic stratum: the sharp mass and the exact charge as one theorem (Q1, Q2)

Now the building starts, and it starts at the center of gravity. This Part proves the paper's central claim, and the claim is one sentence: *the proton is the unique Ground Geometric Attractor — the GGA — of the baryonic stratum.* That is the same kind of statement the sister paper made for the electron (§10); here it is made for the particle at the foundation of all ordinary matter. Read in the plain-English gloss of Part II, a GGA is the *terminal basin* of a landscape — the lowest resting place matter can reach, with no gate leading anywhere deeper — and that image will serve throughout; but the concept doing the work is the GGA, because it is the GGA, not merely a deep valley, that ties the proton to the electron, to the atom, and to every rung of the Chain of GRIP-Out above it (§9). Everything in the eleven-question list is a corollary of that one sentence. This Part spends it first on the two oldest questions: why the proton has one exact mass (Q1) — because the mass is the *depth* of the ground basin, and a depth does not come in variants — and why its charge cancels the electron's to twenty-one digits (Q2) — because the charge is the ground basin's exact label. The remaining questions read the same basin from other sides: the spin is its readout label (Part IV), the confinement of its quarks is why the stratum has a boundary at all (Part V), and the immortality that makes it a GGA rather than a merely-deep attractor is the gauged winding of Part VI. Everything later in the paper stands on what happens in these pages; a reader with time for only one technical Part should choose this one.

18 The question the century could not ask

Begin with what "sharp" means, because the whole Part turns on it.

A composite object in quantum theory does not automatically have *a* mass. It has a spectrum. Strike a bell and you hear a fundamental and its overtones, each with a width — each ring dies away. The hadrons are like this: the $\Delta(1232)$ has a mass of roughly 1232 MeV and a width of 117 MeV (Navas et al., 2024), meaning it survives for about 5×10^{-24} seconds and its "mass," measured event by event, scatters across a hundred-MeV band. Nearly every entry in the baryon tables is such a resonance: a bump, not a number.

The proton is not a bump. Its mass,

$$m_p = 938.272\,088 \text{ MeV}, \tag{9}$$

is a true point in the spectrum: the width is not small, it is *zero* — no strong width, no electromagnetic width and, so far as four decades of watching can tell, no weak width either. And the point is

universal. The proton in a Kamioka water molecule, the proton in a Fermilab argon nucleus, the proton that left a quasar ten billion years ago — every one presents the identical number (9), to every digit ever measured.
Now put this against what the proton *is*. The three valence quarks' Higgs-coupled masses total about 9 MeV — we will price this precisely in §21 — roughly one percent of (9). The other ninety-nine percent is the chromodynamic storm: gluon field energy and a boiling sea of quark–antiquark pairs, a system so violently interacting that no perturbative expansion converges anywhere near it. The century's instruments took the proton apart into that storm; what no instrument explains is why the storm, everywhere and always, *adds up to the same exact number with no width at all.*

Physics intuition: why this should astonish you. Imagine being told that every hurricane on Earth — every one, regardless of where it formed or what it swallowed — carries exactly the same total energy, to twenty-one digits, forever. You would not call that meteorology; you would call it a conservation law wearing a costume, and you would go looking for the law. Q1 is that situation, in miniature, in every atom.

For the reader in the tank. This question is not decoration for your thesis; it is its unstated first axiom. Super-Kamiokande's fiducial mass of 22.5 kton of water holds about 7.5×10^{33} protons — 22.5×10^{9} g of water at ten protons per eighteen grams per mole. A decay search sums over all of them as if they were one object observed 7.5×10^{33} times, and Hyper-Kamiokande will make that $\sim 6 \times 10^{34}$, and DUNE will do the same with the protons of argon. The entire logic of a partial-lifetime limit — $\tau/B > N_p\, t\, \epsilon/2.3$ at 90% confidence for zero observed events — rests on the premise that "the proton" is a single, exactly reproducible physical object rather than a family of near-copies. Q1 asks why that premise is true. This Part answers: because the proton is not *an* arrangement of its storm; it is the *floor* of a landscape, and floors do not come in variants.

19 The stratum, the landscape, and the Ground Geometric Attractor

We now set the stage with the precision the claim requires. Three definitions, each inherited (Part II) and each doing exact work.

The stratum. A *stratum* is the set of boundary configurations sharing the exact conserved labels of the theory. For this Part the labels are three: baryon number $B = 1$ — which Part VI establishes as the winding of the compact cycle, an exactly conserved topological index; electric charge $Q = +1$ — the winding of the electromagnetic fiber, exactly conserved because $\mathrm{U}(1)_{\mathrm{EM}}$ is unbroken; and the fermionic readout label $J = \frac{1}{2}$ of the boundary spinor (Part IV's subject). The *color-singlet* qualifier is automatic rather than imposed: as Part V develops, color has no boundary readout channel, so every element of a boundary stratum is a singlet by construction. The neutron is *not* in this stratum — it shares B and J but sits at $Q = 0$; it is the neighboring stratum's story, told in Part VIII. Strangeness and the excited tower populate the same (B, Q) strata at higher levels; they are Part IX's rungs.

The landscape. On each stratum the free-energy functional GFF of GG-A6-GRIP (Arisaka, 2026, A6-GRIP) assigns to every configuration its cost; the GDOS projection (Arisaka, 2026, A5-GDOS) determines which configurations are boundary-readable at all, and its tower theorem organizes them into floors. "Landscape" is not a metaphor here: it is the graph of GFF over the stratum, and the dynamics of any non-stationary configuration is descent on it, priced by GRIP-In.

The attractor, and the ground attractor. A *basin* is a local minimum of GFF on the stratum together with its attraction region — in the runtime vocabulary of Part II, a Geometric Attractor (GA): a stable configuration. But most basins are not the story's end. A basin is a GA that is *not* the ground attractor if a descent channel still leaves it toward a deeper basin — an open exit, down which GRIP-In continues. Every excited baryon is such a GA (that is why it exists long enough to be named, and why it then decays); the free neutron is such a GA (Part VIII walks it down its one open channel). A basin is the *ground* attractor — the GGA, the *terminal basin* in plain terms — when it is the global minimum of the stratum: no configuration sits lower, so the exit-channel set is empty and GRIP-In halts there. Only a GGA can have exactly zero width, because width *is* the inverse lifetime of a descent, and a global minimum has nowhere to descend to. The distinction is the one Part II drew in general and this Part now applies: a GA is stable against a nudge; the GGA is stable against eternity.

Physics intuition: the landscape is real because the widths are graded. Look at the baryon tables with this picture in mind and they reorganize themselves into GAs ranked by how far they sit above the ground. The $\Delta(1232)$ sits a shallow 294 MeV above the nucleon with a strong-descent channel wide open: it is a GA with a fast exit, width 117 MeV. The $\Lambda(1116)$ has its strong channels closed by strangeness and must descend through the gate force: a GA with only a slow exit, width 2.5×10^{-12} MeV. The neutron's last channel is a 1.293 MeV chink: a GA with a barely-open exit, width 7.5×10^{-25} MeV. The proton: no exit at all — the GGA, width zero. Four objects, widths spanning twenty-six orders of magnitude, and the single organizing variable is *how far above the ground attractor you sit and what channel the labels leave open.* The landscape is not decoration; it is the only picture in which that twenty-six-order column reads as one fact — and the bottom of the column, the one object with no exit, is the GGA this Part is about.
Figure 8 draws the landscape this Part has been describing — the tower's basins above, the shallow twin one wall over, and the ground attractor at the bottom with no gate out of it (the *terminal basin*, in the plain-English gloss). Every claim of the next section is a statement about this picture.

20 The ground-attractor theorem

Theorem 20.1 (**T-P6-3**: The proton is the Ground Geometric Attractor of the baryonic stratum)**.** *On the stratum* $(B, Q, J) = (1, +1, \frac{1}{2})$ *of the boundary, the free-energy functional GFF has a Ground Geometric Attractor (GGA), and the proton is its readout. Concretely:* (i) *GFF attains a minimum (a GA exists);* (ii) *the minimizing basin is unique;* (iii) *it is the* ground *attractor, not merely a deep*

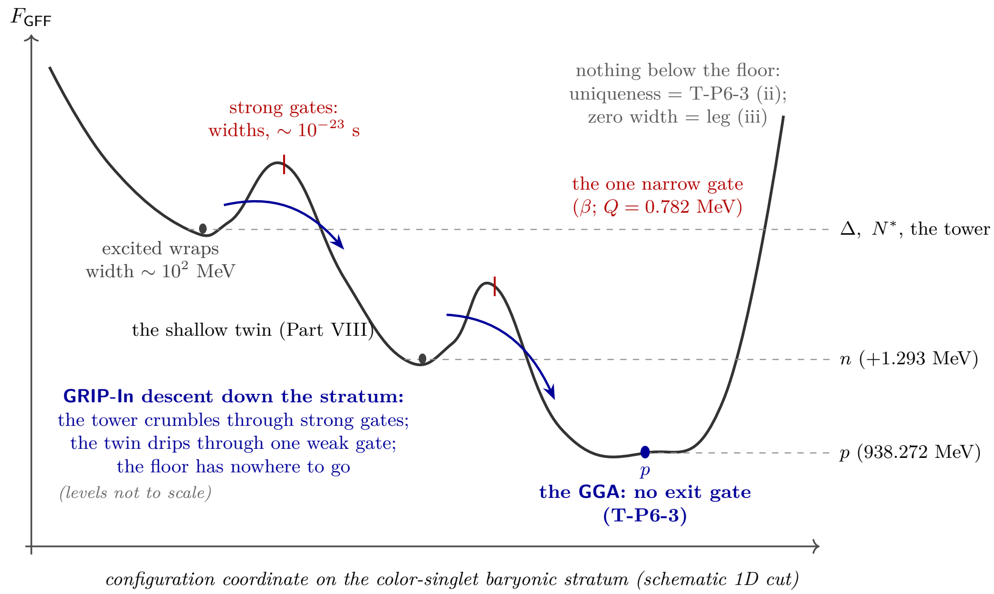


Figure 8: The baryonic stratum in one picture: a schematic one-dimensional cut through the GFF landscape for color-singlet three-quark matter. The excited tower (Δ, N^*, the hyperon shelf) occupies the upper basins, each with wide strong-interaction gates (lifetimes ∼ 10^{-23} s); the neutron sits 1.293 MeV up-slope of the floor with exactly one narrow gate (β-decay, endpoint 0.782 MeV — Part VIII walks through it); and the proton is the floor itself: the unique deepest basin, with no gate out — the ground-attractor theorem T-P6-3 of this Part. The sharp mass (Q1) is the floor's depth; the zero width is its terminality; identity of all readouts is the uniqueness leg. The winding that forbids tunneling out of the stratum entirely is Part VI's business.

one — every decay channel out of it is closed by the exact labels, so its exit-channel set is empty and its readout has width exactly zero; and (iv) *every readout of that GGA, anywhere on the boundary, presents identical observables. The proton is that Ground Geometric Attractor.*

The four legs are exactly the definition of a GGA unpacked into checkable statements. Legs (i) and (ii) establish that a *unique* deepest basin exists — the "ground" and "attractor" of the name. Leg (iii) is the clause that distinguishes a GGA from a mere GA: not stability against a perturbation, but the empty exit-channel set — GRIP-In halts here because there is nowhere deeper to go. Leg (iv) is the universality that GGA-hood forces, the same clause that makes every electron identical in the sister paper (§10), here transposed one stratum over. Each is established at a stated grade, one at a time; the status ledger of §28 records the grades. The reader should notice the division of labor that the rest of the paper will honor: legs (i), (ii), and (iv) are properties of the *landscape*, provable on this stratum with the machinery already in hand; leg (iii) — the *exactness* of "no deeper valley," the clause that promotes the proton from a very deep GA to a true GGA — is the one that must be defended against the grand-unified operators that would open an exit, and that defense is the gauged winding of Part VI. In one line: *Part VI is the proof that the proton's exit-channel set is not merely small but exactly empty — the proof that the baryonic ground attractor is a GGA.*

Leg (i): existence (a GA exists). The GDOS tower theorem guarantees the stratum's spectrum is organized in floors bounded below — the functional cannot run to $-\infty$, because the boundary projection of a bulk with a stable action (GG-A1-Constitution AX-2's single variational principle; the BI-6 capacity that gives GG-P2-N3 its upper leg, its capacity theorem T-N3-6) admits no bottomless direction. This is the structural statement; its empirical shadow is nonperturbative QCD's own existence statement, verified on the lattice for four decades (Wilson, 1974; Dürr et al., 2008): the $B = 1$ spectrum has a lowest state. Grade: derived within the framework's imports; independently confirmed numerically in the standard theory.

Leg (ii): uniqueness (the attractor is unique). Suppose two distinct minimizing basins on the stratum. Both are boundary-readable zero-width states with identical exact labels $(1, +1, \frac{1}{2})$ — the situation the sister paper's identity theorem (Arisaka, 2026, P3-Electron) excludes for the leptonic stratum, and the argument transposes: two degenerate ground attractors of one stratum either (a) are connected by a configuration path, in which case the higher saddle makes one of them non-ground — contradiction; or (b) are disconnected within the stratum, in which case a conserved label distinguishes them — contradiction with the stratum's definition, since the labels of the theory are exactly the winding pair and the spinor label (a fourth exact boundary label would be a fourth exact symmetry, which the constitutional inventory of GG-A1-Constitution does not contain). Empirically: eighty years of hadron spectroscopy have found exactly one zero-width $B = 1$ state, and every "second proton" candidate has resolved into an excited GA with a width. Grade: derived, conditional on the completeness of the constitutional label inventory — the fence is named in the ledger.

Leg (iii): terminality — the zero width. A decay needs a destination: a configuration of strictly lower GFF reachable while conserving every exact label. Walk the candidate channels. *Strong and electromagnetic descents* preserve all labels but need a lower $B = 1$ floor — there is none; the proton is the floor (legs i–ii). *Gate-force (weak) descents* can move within and between strata — it is exactly how the neutron dies (Part VIII) and the muon before it — but the gate conserves B and Q, and the $B = 1$ floor of the charged stratum has no lower relative anywhere: the lightest $B = 1$ configurations of *any* charge are the nucleon pair, and the proton undercuts both members. *B-violating descents* — the channels Georgi–Glashow opened on paper (Georgi and Glashow, 1974) — are closed to all orders by the winding selection rule of Part VI: $\Delta B = \pm 1$ operators carry non-zero winding charge and have identically vanishing coefficients, the sole exception being the topological $\Delta B \in 3\mathbb{Z}$ vertex ('t Hooft, 1976), frozen at $e^{-4\pi/\alpha_W} = e^{-372} \approx 10^{-162}$, a rate whose reciprocal exceeds the age of the universe by so many orders that writing the number is theater. Hence: width exactly zero, with the B-conservation leg carried at Part VI's grade (conditional on H3 and the pins R2, R3 — the fences travel with the theorem, as always). Grade: derived conditional, clauses as stated.

Leg (iv): identity of readouts. A basin has no adjustable interior: it is a stationary point of a functional determined by the geometry, and a readout of it reports the stationary values, not a history of how the configuration got there. Two protons cannot differ, because there is nothing in the basin for them to differ *by* — exactly the argument that made every electron identical in the sister paper, transposed to the stratum one winding over. The lattice gives the standard theory's version of the same fact: the simulation needs only the coupling and the quark masses — no per-proton dials — and returns the measured mass (Dürr et al., 2008). Grade: derived, given legs (i)–(iii).

Physics intuition: the storm is the bulk's business. The apparent paradox of Q1 — exact number from boiling storm — is a custody confusion. The storm (the sea, the gluon flux, the virtual pairs) is *bulk* structure: real, physical, doing 99% of the energetic work, and not itself a boundary observable. The boundary reads the stationary value of the functional the storm extremizes — one number — just as a barometer reads a pressure without reading the position of any molecule. The proton's sharpness is not the storm holding still; it is the floor of the landscape being where it is regardless of how the storm rages above it. *The proton is not a thing the storm builds; it is the place the storm settles.*

The ground that everything stands on. The theorem has been stated looking downward — the proton as the bottom of the baryonic descent, the basin with no exit. That is leg (iii), and it is true. But the reason this theorem is the center of the paper, and arguably of the framework, is what it means looking *upward*. A GGA is not only an endpoint; it is a *foundation*. Because the proton's exit-channel set is exactly empty — because it is a GGA and not a slowly-draining GA — it can serve as permanent substrate for the next GRIP-Out event in the Chain of §9: cooling lets electrons fall onto nuclei built from protons, and the atomic stratum opens; chemistry lets atoms bond, and the molecular stratum opens; and so upward through amino acids, proteins, ATP, RNA, DNA, and every rung above. Each of those strata has its own GGA, and each stands on the one below — but the whole tower stands, ultimately, on the proton holding still *forever*. A proton that were only a very deep GA, draining on some finite timescale, would be a foundation with a shelf life, and the periodic table and everything built from it would inherit that shelf life. That matter is instead permanent enough to assemble a chemist who can ask why is a statement about the proton being a GGA — and it is why the search under the mountain (Part VII) is not a search for a rare event but a test of whether the foundation of the material world is, as this theorem claims, exactly and not approximately eternal. The sharp mass and the exact charge that the rest of this Part prices are the two faces of that foundation stone; the immortality that makes it load-bearing is Part VI's.

21 The depth of the basin: pricing 938 MeV

Ground-state-ness explains why the mass is *sharp*; it does not yet say why it is *that* number. The pricing has three stories, told here with every step shown — the arithmetic is walked digit by digit in Appendix A.

21.1 The mechanism: a scale from no scale

Chromodynamics with massless quarks contains no mass parameter at all, and nevertheless produces the proton. The mechanism — dimensional transmutation (Gross and Wilczek, 1973; Politzer, 1973) — is the single most important calculation a student of the strong force ever does, so we do it.

The coupling runs. At one loop,

$$\mu \frac{d\,\alpha_s}{d\mu} = -\frac{b_0}{2\pi}\,\alpha_s^2, \qquad b_0 = 11 - \tfrac{2}{3} n_f, \tag{10}$$

where n_f counts the quark flavors light at the scale μ. The 11 is the gluons' own anti-screening — the non-Abelian signature — and the $-\frac{2}{3}n_f$ is the familiar screening by quark pairs; as long as $n_f \leq 16$, $b_0 > 0$ and the coupling *grows* toward the infrared. Integrating (10) from μ down,

$$\alpha_s(\mu) = \frac{2\pi}{b_0 \ln(\mu/\Lambda)} \qquad \Longleftrightarrow \qquad \Lambda = \mu\, \exp\!\left[-\frac{2\pi}{b_0\, \alpha_s(\mu)}\right]. \tag{11}$$

Stare at the right-hand form. Λ is a *renormalization-group invariant*: compute it from the coupling at any μ and you get the same number. A dimensionless input α_s plus an arbitrary reference scale μ have conspired to produce a *physical* scale — and produced it non-perturbatively, through an essential singularity $e^{-2\pi/b_0\alpha_s}$ that no order of perturbation theory can see. Where the coupling reaches strength, $\mu \sim \Lambda$, perturbation theory dies, confinement reigns, and the hadrons live. The proton's mass is, up to a pure number that nonperturbative dynamics fixes, *this* Λ.

Physics intuition. The exponential is the whole point. The proton is light compared to the unification scale not because someone tuned a small parameter but because $e^{-2\pi/b_0\alpha_s}$ is *automatically* minuscule for a moderate coupling — hierarchy from arithmetic, not adjustment. When you wonder why matter's mass scale sits seventeen orders below the seam, the answer is an exponent.

21.2 The input: a derived coupling

Standard physics runs this machine backward: measure $\alpha_s(M_Z)$, infer Λ, take the hierarchy as explained-but-unanchored. What the framework adds — and this is an import, priced at its home's grade — is the input itself. GG-A9-SM registers the strong coupling at the M_Z seam as

$$\alpha_s^{-1}(M_Z) = \pi e = 8.5397 \implies \alpha_s(M_Z) = 0.11710, \tag{12}$$

against the world average 0.1180(9) — a deviation of −0.76%, a pull of −0.70, first order, no fitted prefactor, with the QD completion carrying the residual at the home paper's declared register (Arisaka, 2026, A9-SM). Every number in the walk below therefore contains *zero* experimental input from the strong sector: it flows from the registration (12) through the standard machinery (10)–(11) alone.

What exactly does GG-A9-SM claim for (12), and at what grade? Since the entire closure below stands on this input, the reader deserves the answer here and not in a footnote. In GG-A9-SM's strong angle–scale theorem, the inverse coupling read at the M_Z seam is the *universal scale constant* πe — the product of the two primitives the seam geometry owns: π, the half-circle of the compact phase direction, and e, one e-fold of the scale direction. A coupling, in the open-system reading, is a *capacity* of the seam — how much angular structure per unit scale the projection can register — and GG-A9-SM's claim is that the color seam's capacity is fixed by the geometry at exactly πe, with no tunable coefficient and no scheme knob at first order. It is a closed form, not a fit.

And it carries its audit in the open, which is what “GG-A9-SM’s grade” means whenever this paper says it. In GG-A9-SM’s codebook the entry is **Derived (selected)**: the closed form πe is fixed by the framework’s cost-minimum selection, and the audit honestly reports that recognizing πe among candidate closed forms used the measured value as the selection filter, with the look-elsewhere probability ($p \approx 0.27$) printed beside the claim rather than buried. The first-order value 0.11710 then deviates from the world average 0.1180(9) by -0.76% — a pull of -0.70 — with the QD completion carrying the residual at GG-A9-SM’s declared register. This paper adds nothing to that claim and defends none of it here; it *consumes* it, at exactly that grade, with exactly those fences. What the next subsections show is what the consumption buys: with this single registration, the strong sector’s one experimental input drops out of the proton’s mass entirely.

21.3 The walk: from the seam to the proton

Carry (12) down through the flavor thresholds at one loop (all steps in Appendix A; thresholds at the PDG $\overline{\text{MS}}$ masses $m_b = 4.18$ GeV, $m_c = 1.27$ GeV (Navas et al., 2024)):

$$\begin{aligned} n_f = 5: &\quad b_0 = \tfrac{23}{3}, \quad \Lambda^{(5)} = M_Z\, e^{-2\pi/(b_0\alpha_s)} = 83 \text{ MeV}, \\ n_f = 4: &\quad b_0 = \tfrac{25}{3}, \quad \Lambda^{(4)} = 114 \text{ MeV}, \\ n_f = 3: &\quad b_0 = 9, \quad\;\; \Lambda^{(3)} = 136 \text{ MeV}. \end{aligned} \tag{13}$$

The exponent at the first step is $2\pi/(b_0\alpha_s) = 7.00$: the factor $e^{-7} \approx 9 \times 10^{-4}$ is the hierarchy being manufactured before your eyes — ninety-one GeV in, eighty-three MeV out, no small parameter anywhere.

Honesty about the last step, because this paper does not launder precision. One loop is the pedagogical transport, and it understates Λ: the world’s four-loop, lattice-matched value is $\Lambda^{(3)}_{\overline{\text{MS}}} \approx$ 340 MeV (lattice-matched determinations span roughly 330–345 MeV) (Navas et al., 2024), against which the lattice’s parameter-free result (Dürr et al., 2008) fixes the pure number

$$\frac{m_p}{\Lambda^{(3)}_{\overline{\text{MS}}}} \approx \frac{938}{340} \approx 2.8. \tag{14}$$

The division of labor is then exact: the framework supplies the dimensionless input (12) (its claim, at its grade); the renormalization group supplies the exponential descent (standard, exact in mechanism, scheme-dependent in digits); the lattice supplies the pure number (14) (standard, nonperturbative, no dials). What no one supplies — what does not exist anywhere in the chain — is a per-proton adjustment. That absence is Q1’s answer wearing numbers.

21.4 The closure: the proton’s mass with no strong-sector input

Now assemble the pieces — because assembled, they say something this paper has not yet said out loud, and something no other account surveyed in this Part says at all. The chain, with every link’s custody attached:

$$\underbrace{\frac{M_{\rm Pl}}{2}}_{\substack{\text{the seam}\\\text{(geometry)}}} \xrightarrow[\text{GG-A9-SM, at its grade}]{\alpha_s^{-1}(M_Z)=\pi e} \underbrace{\alpha_s(M_Z)}_{\substack{\text{no fit,}\\\text{no dial}}} \xrightarrow[\text{standard, exact}]{\text{RG transport}} \underbrace{\Lambda}_{\substack{\text{the scale,}\\\text{priced}}} \xrightarrow[\text{lattice, no dials}]{\times 2.76} \underbrace{m_p}_{\text{938 MeV}} . \tag{15}$$

Every link is already on the table: the registration is (12); the transport is (10)–(11) run through the thresholds of (13); the pure number is (14). What remains is to ask the chain the quantitative question: *how well does it do?*

The answer is governed by one derivative, and the reader should compute it once by hand, because it is the whole story of precision in this subject. From $\Lambda = \mu\, e^{-2\pi/b_0\alpha_s}$,

$$\frac{\partial \ln \Lambda}{\partial \ln \alpha_s} = \frac{2\pi}{b_0\,\alpha_s} = \frac{6.2832}{7.6667 \times 0.1180} = 6.95 \qquad (\text{at } M_Z,\ n_f = 5): \tag{16}$$

the very exponent that manufactures the hierarchy amplifies any error in the input by the same factor of seven. The registration's first-order deviation, -0.76% on the coupling, therefore becomes $6.95 \times (-0.76\%) = -5.3\%$ in this single-step linearization — and -4.5% when, instead of linearizing, the full one-loop walk of (13) is simply re-run with the registered input in place of the measured one (the thresholds soften the magnification, because b_0 grows as flavors decouple). The chain's verdict, stated at the walk's own order:

$$\frac{\delta\Lambda^{(3)}}{\Lambda^{(3)}} = -4.5\% \qquad \Longrightarrow \qquad m_p^{\rm pred} = 938.272 \times (1 - 0.045) \approx 897\ \text{MeV}. \tag{17}$$

Read the sentence that equation is: *taking the framework's registration in place of the measured coupling, and touching nothing else, the mass of the proton comes out at roughly* 900 *MeV — correct to five percent — with zero experimental input from the strong sector at any point in the chain.* The registration is a closed form; the transport is the same renormalization group every textbook derives; the pure number is the lattice's, computed from the gauge theory with no dials. There is no strong-sector measurement anywhere upstream of the answer.

Two honesty clauses travel with that sentence, permanently. *First*, the pure number 2.76 is an import: the chain *predicts* Λ, and rides the lattice from Λ to m_p exactly as declared at (14); the program that would derive this last import inside the framework is registered in §24.1, with its kill window. *Second*, five percent is the *first-order* registration's accuracy, and the claim inherits every fence of its input: GG-A9-SM's selection audit (the look-elsewhere factor of the previous subsection), and GG-A9-SM's QD completion carrying the residual at GG-A9-SM's register. Whether the completed registration lands closer than five percent is GG-A9-SM's claim to defend, not this Part's; nothing downstream of (17) leans on it.

With the fences up, state the significance plainly, because calibrated honesty cuts both ways and this is the strong direction. Q1's deepest clause — OP-1 of §24, "the value of the strong scale itself" in the honest status table of Part I — is the one every standard account marks *input*: dimensional transmutation prices ratios, the lattice computes spectra from a measured coupling, grand unification relates couplings to one another but takes their overall registration from experiment, and no account surveyed in this Part derives the number. Within this framework the number is derived — at a stated grade, with a published audit, first order, −0.76% on the coupling and five percent on the mass — and the twenty-order hierarchy between the Planck seam and your body's protons reduces to arithmetic: 44.3 e-folds, of which 7.0 are the single exponential step $e^{-2\pi/b_0\alpha_s}$ read off at M_Z. To this paper's knowledge, this chain — Figure 9 draws it to scale — is the only one in the current literature that prices the proton's mass from a geometric constant, and every one of its links is either standard physics or a registered, falsifiable claim of this cohort.

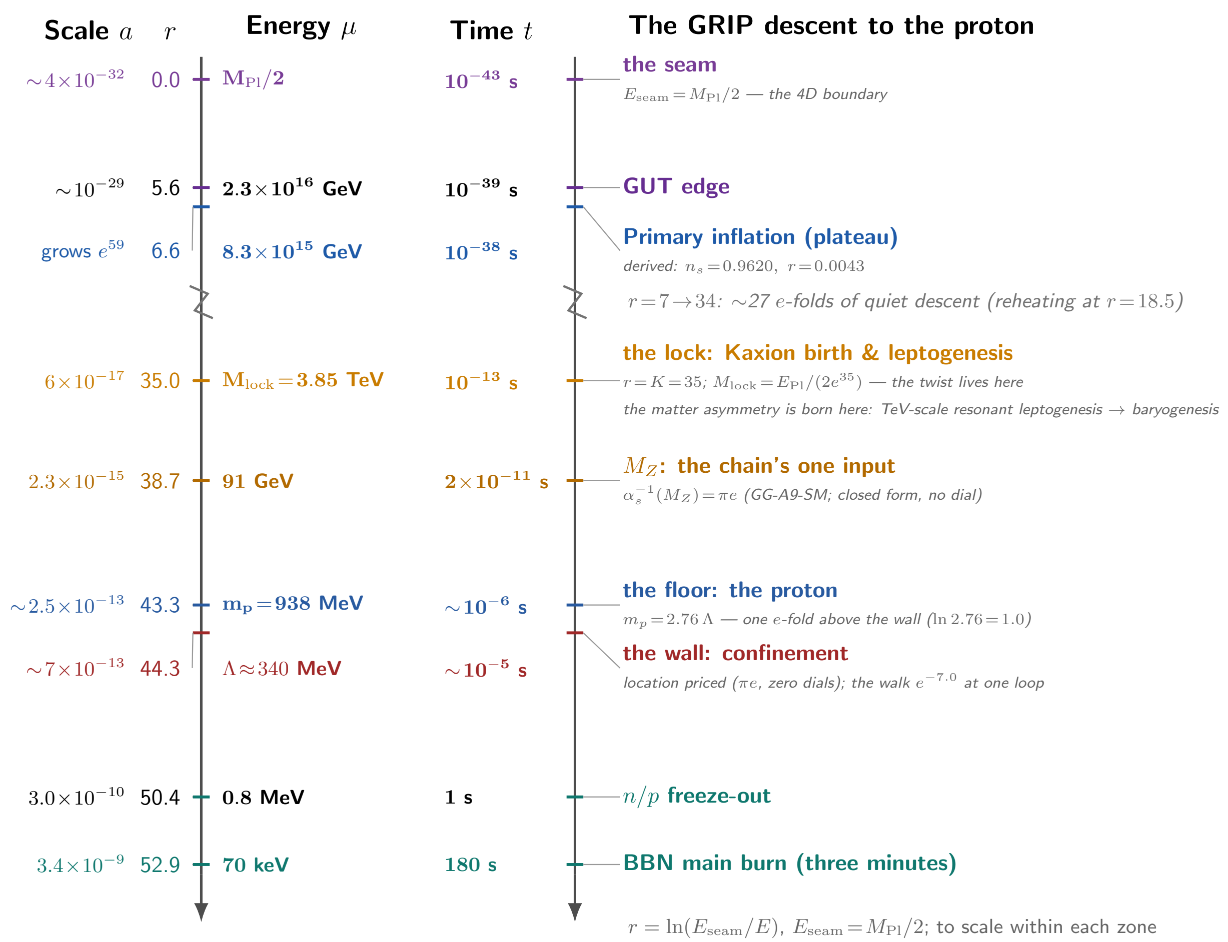


Figure 9: The closure (15) drawn to scale on the e-fold axis $r = \ln(E_{seam}/E)$, read down four quantities — the scale factor a, the depth r, the bath energy μ, and the cosmic time t. From the seam ($r = 0$), the descent passes the lock at $r = K = 35$ — where TeV-scale resonant leptogenesis seeds the matter asymmetry that becomes the baryons (GG-A10-Cosmos, GG-A11-Origin) — reaches M_Z at $r = 38.7$ — where the chain's single input, the registration $\alpha_s^{-1}(M_Z) = \pi e$, is read from the geometry — and lands on the color wall at $r_\Lambda = 44.33$, with the proton's floor one e-fold ($\ln 2.76 = 1.0$) above it; the axis then continues to the onset of nucleosynthesis. Nothing on this axis is fitted: the seam and lock are the cohort's, the registration is GG-A9-SM's closed form at its published grade, the transport is the textbook renormalization group, and the last step is the lattice's dial-free 2.76. The chain prices the proton's mass at roughly 900 MeV — five percent — with no strong-sector measurement anywhere in it — see (17); fences in the text.

Physics intuition: the telescope and the shake. Why five percent from an input good to three quarters of a percent? Because the transmutation exponential is a telescope: it magnifies a modest coupling into a twenty-order hierarchy, and it magnifies the input's error by the same optics — (16) is the magnification, $\times 7$. This is not a defect of the framework; it is a property of the subject. *Any* theory that ever derives the proton's mass from first principles must push its prediction through this same telescope, and will pay the same factor. The honest comparison is therefore at the input: -0.76% on the coupling, pull -0.70 — and the telescope's optics, being standard physics, are the same for everyone.

21.5 The one percent: the Higgs tolls

The current-quark masses enter the basin's depth as small tolls:

$$2m_u + m_d \;=\; 2(2.16) + 4.67 \;=\; 8.99\ \text{MeV} \;=\; 0.96\%\ \text{of}\ m_p \tag{18}$$

(PDG $\overline{\text{MS}}$ values (Navas et al., 2024); the PDG's lattice-average set, $m_u = 2.20$, $m_d = 4.69$ MeV, gives 9.09 MeV $= 0.97\%$ — either way, under one percent). Precision about what that number *is*, because the research literature is more careful here than the outreach: 0.96% is the *valence current-mass sum* — the Lagrangian masses the Higgs writes for the three quarks on the label.

The proton's full *response* to the Higgs is larger, and this paper reports it rather than rounding it away. Switch the light-quark masses off entirely and the proton's mass drops not by 9 MeV but by the sigma terms — the derivatives of m_p with respect to the quark masses, summed: the pion–nucleon term $\sigma_{\pi N} = 43.7(3.6)$ MeV and the strangeness term $\sigma_s = 28.6(9.3)$ MeV on the current lattice determination (Agadjanov et al., 2023), roughly 72 MeV together — *seven to eight percent* of the mass, not one. Even that number is live physics rather than settled bookkeeping: $\sigma_{\pi N}$ from pion–nucleon scattering phenomenology runs near 59 MeV, the lattice's standard analyses near 42 MeV, the tension stands at 2.4σ (Agadjanov et al., 2023), and one lattice study has shown the *same ensembles* moving from 41.9(4.9) to 59.6(7.4) MeV — two percent of the proton — depending on how $N\pi$ excited states are treated (Gupta et al., 2021). And the ledger grows subtler still upstream: the sigma terms of the *heavy* quarks are sizable (the charm term alone is of order 100 MeV in current estimates), but whether they count as "Higgs" at all is convention — heavy quarks decouple into the gluon condensate, so their share can be booked to either column (Metz et al., 2020). The slogan, then, in its honest final form: *the Higgs writes valence tolls of under one percent; its full sigma-term response is several percent and currently under dispute at the two-sigma level; and confinement pays all the rest. You weigh what your protons' fields are doing, not what their parts are.* The tolls do carry structural weight far beyond their percent — the $m_d - m_u$ difference tips the neutron–proton competition and with it the existence of chemistry — but that is Part VIII's story, and it is told there.

Figure 10 shows the completed pricing as one bar: the basin's depth is almost entirely the strong interaction's own scale, with the Higgs sector entering as a toll of under one percent.

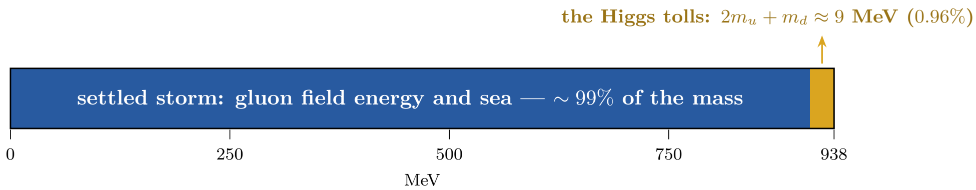


Figure 10: The mass budget of the proton as this section has priced it. Nearly all of the 938.272 MeV is the settled storm — gluon field energy and sea, the basin depth set by the strong scale, itself priced by the registration $\alpha_s^{-1}(M_Z) = \pi e$ and the one-loop walk of §21 — while the Higgs-coupled valence masses enter as tolls of $2m_u + m_d \approx 9$ MeV, below one percent. The bar is the answer to Q1's second half: an object that is 99% interaction energy has one exact mass because the *basin* is exact, not the parts. The bar prices the *valence* tolls; switching the quark masses off entirely would cost the proton the full sigma-term response — roughly 70 MeV, several percent (§21.5) — and its immortality nothing at all. The proton weighs what its geometry costs, not what its parts weigh.

22 The storm, itemized: the century's ledgers, and why they argue

Section 21 priced the depth of the basin from above — from the seam down, through the registration and the renormalization group. This section and the two that follow price it from *inside*, the way the century has: by asking where, within the proton, the 938 MeV actually resides. The question sounds innocent. It is not. It has been the subject of a thirty-year argument among some of the field's best theorists, an argument that reached a remarkable milestone while this paper was being written — and the resolution this framework proposes for it is the same one it proposed for the spin crisis one Part from now. A reader who works through this section will own the whole modern literature of the proton's mass budget: what is measured, what is convention, and what the argument is actually about. That is a deliberate design goal — this Part is written to serve as a self-contained review of the subject as well as this framework's account of it.

22.1 The four-term ledger

Begin with the object everything hangs on: the energy–momentum tensor $T^{\mu\nu}$, the operator that says where energy and momentum sit. The proton's mass is its rest-frame energy,

$$m_p \;=\; \frac{\langle p|\int d^3x\, T^{00}(x)\,|p\rangle}{\langle p|p\rangle}\Big|_{\text{rest frame}}, \tag{19}$$

and since QCD writes T^{00} as a sum of operators — quark kinetic terms, gluon field energy, quark mass terms — one can ask each operator for its share. In 1995 Xiangdong Ji organized this into a theorem-grade budget (Ji, 1995): using exactly two QCD inputs, the deep-inelastic momentum sum rule (which fixes how quarks and gluons split the proton's momentum, and hence their kinetic energies) and the trace anomaly of the energy–momentum tensor, the mass separates into four pieces — quark kinetic and potential energy, the quark masses (a sigma-term-like piece), the gluon field energy, and the trace anomaly.

The fourth piece deserves its own paragraph, because it is the deepest and the most argued-over. Classically, chromodynamics with massless quarks has no scale, so the trace of its energy–momentum tensor — the operator that measures how the theory responds to a change of scale — vanishes identically. Quantum mechanically it does not:

$$T^{\mu}{}_{\mu} \;=\; \frac{\beta(g)}{2g}\, G^{a}_{\mu\nu} G^{a\,\mu\nu} \;+\; (1+\gamma_m)\sum_q m_q\, \bar{q}q, \tag{20}$$

where $\beta(g)$ is the same beta function that ran the coupling in (10). The first term is the *trace anomaly*: scale invariance broken not by any mass in the Lagrangian but by quantization itself. The reader should pause on what (20) is: it is dimensional transmutation written as a local operator. The global statement "the running coupling manufactures a scale" and the local statement "the trace of $T^{\mu\nu}$ fails to vanish by an amount proportional to β" are the same physics in two dresses. When this section argues about "the anomaly's share of the mass," it is arguing about how much of the proton's weight to book under the line item *scale generation itself*.

In 2018 the χQCD collaboration computed Ji's four entries on the lattice (Yang et al., 2018) — the first complete first-principles itemization of the proton's mass. Their ledger, in the $\overline{\text{MS}}$ scheme at $\mu = 2$ GeV:

Table 4: The proton's mass itemized on the lattice (Yang et al., 2018), in the Ji decomposition, $\overline{\text{MS}}$ at $\mu = 2$ GeV. First error statistical, second systematic. The four central values sum to 102%, consistent with 100% within the quoted uncertainties (the anomaly entry is fixed partly by the sum rule). The scheme-and-scale stamp in the caption is not decoration; it is the point of the next subsection.

Entry (Ji ledger)	**Share of m_p**
Quark energy (kinetic + potential)	33(4)(4)%
Gluon field energy	37(5)(4)%
Quark scalar condensates u, d, s (sigma piece)	9(2)(1)%
Trace anomaly (one quarter of it)	23(1)(1)%

Read as a physical picture, the table says: roughly a third of your weight is the kinetic fury of quarks that cannot sit still in a box a femtometer across; a third is the energy of the gluon field that does the boxing; a tenth is the Higgs-coupled condensates; and a quarter is scale generation itself, the anomaly. It is a beautiful ledger, it is the one the outreach articles quote, and the next subsection is about why several of the field's sharpest theorists would tell you — politely, in refereed journals — that three of its four lines are an accounting convention.

22.2 The two-term objection

Here is the difficulty, and it is not a quibble. All the information the forward matrix element of $T^{\mu\nu}$ contains about the proton is carried by exactly *two* independent form factors. Everything else is apportionment. Cédric Lorcé made the case sharply in 2018 (Lorcé, 2018): a hadron seen as made of quarks and gluons "cannot [have its mass] decomposed into more than two contributions without running into trouble with the consistency of the physical interpretation," and in particular the quark-mass and trace-anomaly entries of the standard four-term budgets "appear to be purely conventional"; he further observed that the standard decompositions overlook pressure effects, and proposed his own two-term accounting that tracks them. Metz, Pasquini, and Rodini then made the renormalization-theory version of the argument (Metz et al., 2020): any decomposition of the proton's mass has at most two independent terms, because the forward energy–momentum tensor has only two independent form factors; and when they evaluated the competing sum rules through three loops they found the *individual entries* carry "considerable scheme dependence" even as the total stays put. On their analysis, "how much of the proton's mass is trace anomaly" is not a number nature knows; it is a number a renormalization convention knows.

Ji has answered, in print and at length (Ji, 2021): the four-term budget is the natural one in the proton's rest frame, where the Hamiltonian is the operator being partitioned; the rival "frame-independent" two-term accounting from the trace is a different scheme answering a different question, not a correction; and the quantum anomalous energy — the anomaly's entry — is, he stresses, experimentally measurable, which is the theoretical position underpinning the threshold-charm experimental program of §23. The dispute is live, refereed, and conducted by people who agree completely about every measurable number. That last clause is the tell, and the custody reading below will make it precise.

22.3 The 2026 result: the dispute, measured

While this paper was in preparation, the argument reached the milestone it had been waiting for: a lattice calculation that computes *all four* rival sum rules — Ji's; Lorcé's; Metz–Pasquini–Rodini's; and the Hatta–Rajan–Tanaka trace-based accounting — simultaneously, in a single unified renormalization framework (gradient flow with continuum extrapolation and two-loop matching), for the same hadrons (Bollweg et al., 2026). The hadrons are charmonia (η_c and J/ψ), not the proton — the percentages below must not be quoted as proton shares — but the methodological result is the one that matters here, and it is stark. In one and the same calculation, of one and the same hadron, the "gluonic/anomaly share" of the mass comes out at roughly 15% in the Lorcé and Metz–Pasquini–Rodini accountings, roughly 6% as the trace-anomaly term of the Ji sum rule, and roughly 35% as the gluonic component of the Hatta–Rajan–Tanaka trace decomposition. Same hadron, same lattice, same renormalization framework: shares differing by a factor of six, depending on whose ledger you fill in.

Figure 11 draws this single fact, because it is the fact this whole section turns on: the question "how much of the mass is the anomaly?" returns a different answer for every well-defined way of asking it, while the mass itself — the depth — sits still.

22.4 The custody reading: the mass ledger is the spin ledger at $J = 0$

The reader who has already looked ahead to Part IV will recognize everything in the last three subsections, because the proton has staged this play before, with different props. In the spin crisis, the question "how much of the proton's $\frac{1}{2}$ do the quark spins carry?" turned out to depend on the frame and the gauge-bookkeeping convention — the Jaffe–Manohar and Ji ledgers apportion the same total differently, both self-consistently — and the resolution that Part defends is custody: *a label is not a sum*; the invariant is the total, and the parts are projections that require a convention to

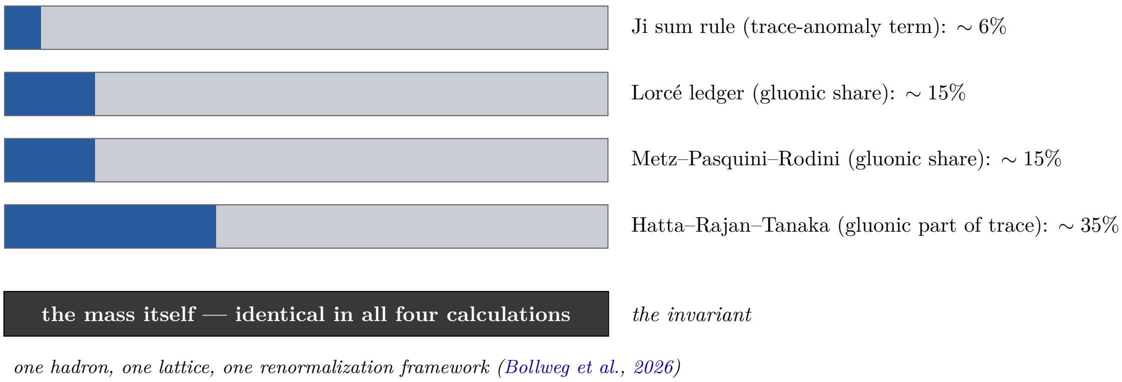


Figure 11: The itemization dispute, measured. The 2026 gradient-flow lattice computation (Bollweg et al., 2026) evaluates all four published mass sum rules for the same hadron (charmonium — *not* the proton; the percentages are scheme-comparison data, not proton shares) in a single renormalization framework. The "anomalous/gluonic" entry — blue — ranges from $\sim 6\%$ to $\sim 35\%$ across the four accountings, while the total mass (bottom bar) is identical in every one. The parts are bookkeeping; the depth is physics. This is the mass-sector face of the custody principle, and the reason this paper prices the basin's depth without ever claiming a unique itemization of it.

define. The mass budget is the same structure at $J = 0$: two invariant form factors' worth of physics, apportioned four ways by one scheme and two ways by another, with the 2026 calculation playing the role the polarized-beam decades played for spin — the demonstration that the itemization moves when the convention does.

This framework's reading adds one structural sentence to that observation, and the sentence is the same one §20 already needed: *the storm is the bulk's business; the boundary reads the stationary value.* In the GDOS account, the sea, the flux, and the virtual pairs whose energies the ledgers apportion are bulk structure — real, physical, and not severally boundary-observable — while the boundary observable is the one number the storm extremizes: the depth of the basin. On this reading the community's stalemate is not an embarrassment to be waited out; it is a *prediction.* The items live in the bulk; itemizing them for the boundary requires choosing a projection; projections are conventions; therefore the itemization argument has no convention-free resolution, and the only number all bookkeepers must share is the depth. The 2026 spread of Figure 11 is what that prediction looks like when a lattice finally computes it.

Honesty about the status of this reading, in the register this paper has used throughout. It is an interpretation (INT grade), not a theorem: it is this framework's structural diagnosis of why the dispute exists, and it takes — for structural reasons, not partisan ones — the side of the two-term camp on the question of what is invariant, while fully agreeing with Ji that scheme-defined entries (his quantum anomalous energy included) are legitimate, computable, and worth measuring *as scheme-defined quantities.* The reading would be embarrassed, and honestly reported as such, if the community converged on a scheme-independent multi-term itemization; the 2026 result moved the other way. And it changes nothing upstream: every number in §21 priced the depth itself, which is exactly the quantity all parties agree on.

Physics intuition: four accountants, one bank balance. A company has one net worth. Four accountants can apportion it — by division, by region, by cost center, by tax year — and each report is internally consistent, auditable, and useful; yet "how much of the net worth is the Tokyo office?" has as many answers as there are accounting conventions, and the board would be foolish to fight over which answer is *true*. What no convention can move is the balance. The proton runs the same books: the ledgers of Ji, Lorcé, Metz–Pasquini–Rodini, and Hatta–Rajan–Tanaka are four audits of one basin, and the basin's depth — 938 MeV, every proton, everywhere — is the balance. This paper's business has been the balance throughout.

23 What the experiments are measuring

The mass budget is not a theorists' private argument; it is a funded experimental program, and the reader this paper is written for — the one on shift in a hall or a tank — has colleagues on it. This section reviews what the experiments actually measure, in the experiments' own words, because the distance between "what the apparatus records" and "what the press release says about the origin of mass" is exactly the kind of distance this paper exists to keep honest.

23.1 Threshold charm: the gluonic proton, approached

The chosen probe is exclusive J/ψ photoproduction at threshold: $\gamma p \to J/\psi\, p$, as close as kinematics allows to the minimum photon energy ($E_\gamma = 8.2$ GeV) that can make a charm–anticharm pair off a proton. The logic of the choice is lovely: the $c\bar{c}$ pair is too heavy to be part of the proton's own sea, so near threshold it must be produced by *gluons* — the probe couples, through a heavy-quark loop, to precisely the gluonic operators whose matrix elements the mass ledgers argue about, including the anomaly term of (20).

The data are recent and beautiful. GlueX at Jefferson Lab made the first measurement of the exclusive threshold cross section in 2019 (GlueX Collaboration, 2019), finding it falls toward threshold *less* steeply than two-gluon-exchange models predicted — the first hint that the simplest theoretical picture was too simple — and seeing no trace of the LHCb pentaquarks in the s-channel. Their full dataset followed in 2023 (GlueX Collaboration, 2023), covering threshold to 11.44 GeV over the full range of momentum transfer, and it sharpened the hint into a finding: there is "evidence for contributions beyond gluon exchange" close to threshold, consistent with open-charm intermediate states ($\Lambda_c \bar{D}$), sitting exactly where the cleanest gluonic interpretation needs the amplitude to be pure.

The discipline to carry away is one the collaboration itself insists on: GlueX frames its measurements as "crucial inputs to theoretical models" of the proton's gluonic structure — the gluon distributions, the mass radius, the anomaly — not as a direct measurement of any of them (GlueX Collaboration, 2023). The anomaly does not sit on a dial in Hall D. It is inferred, through a model, from a cross section — and the 2023 evidence for non-gluonic contamination is a measured caution about every such inference. The reader should hold the threshold-charm program in exactly this register: a genuine experimental approach to the gluonic proton, young, model-mediated, and improving.

23.2 Gravity's form factors, in a hall and on a lattice

There is a second, more audacious way to state what these experiments are after. The operator whose matrix elements the mass ledgers apportion, $T^{\mu\nu}$, is the source of gravity; its off-forward proton matrix elements define *gravitational form factors* — the distribution of energy, momentum flux, and shear inside the proton, the quantities a graviton-scattering experiment would measure if one could be built. No one can scatter gravitons off protons. But the same form factors appear in the theory of the processes above, and so the threshold-charm and Compton-scattering programs are, in a precise if model-mediated sense, doing gravitational spectroscopy of the proton with photons standing in for gravitons.

Three results define the current state of that program.

The mass radius. The dedicated threshold experiment J/ψ-007 at Jefferson Lab (Duran et al., 2023) used its measured cross sections to extract the proton's gluonic gravitational form factors and, from them, a *mass radius* — and found, across every model employed, "a mass radius that is notably smaller than the electric charge radius." The proton's energy is concentrated deeper than its charge. The authors are candid that the extraction is model-dependent (holographic QCD among the frameworks used, with lattice agreement obtaining for some models and not others), and this paper carries their candor with the result. The qualitative ordering, however, survives every model choice made to date: $r_{\text{mass}} < r_{\text{charge}}$.

The pressure claim, and its published rebuttal. In 2018 a CLAS analysis reported the "pressure distribution inside the proton" from deeply-virtual Compton scattering — a repulsive core and a confining exterior, gravity's form factor $D(t)$ read as mechanics (Burkert et al., 2018). It is a landmark *claim*; it is not yet a landmark *measurement*: a published reanalysis showed that with a flexible (neural-network) parameterization, the same data are "consistent with zero quark pressure" — the 2018 signal rides on the rigidity of the fitting model (Kumerički, 2019). This paper cites the pair as a pair, and takes its own lesson from them: extraordinary mechanical claims about the proton's interior currently outrun the data that support them, on all sides of every argument.

The lattice's answer. Meanwhile the full gravitational form factors of the proton — up, down, strange, and gluon separately — have been computed on the lattice (Hackett et al., 2024), with two results that matter here. First, the quark and gluon halves of the proton's momentum budget come out almost exactly even: $A_q(0) = 0.510(25)$ against $A_g(0) = 0.501(27)$, the momentum sum rule closing at 1.011(37) — the storm's energy split published to lattice precision. Second, "the gluon contributions act to extend the radial size of the proton over that defined by the quark contributions": the gluonic proton is the *larger* proton, which dovetails with the hall's finding that the mass (quark-weighted deeper structure) radius undercuts the charge radius. The computation carries its own declared caveats — a heavier-than-physical pion ($m_\pi \approx 170$ MeV), and flavor-separated pressures that depend on a form factor which cancels only in the total — and this paper carries them too.

23.3 The decade ahead, and this framework's stake in it

The community has committed a flagship machine to this subject. The Electron–Ion Collider's Yellow Report lists "how do the nucleonic properties such as mass and spin emerge from partons and their underlying interactions?" among the machine's central questions, states plainly that the valence-quark masses provide "merely about 1% of the proton mass," identifies the trace anomaly as the "essential ingredient for which the EIC can deliver crucial input," and designates threshold quarkonium production — J/ψ and Υ — as the route (Abdul Khalek et al., 2022). The reader now holds the honest version of that program: what will actually be measured is cross sections; what will be extracted, through models whose assumptions the 2023 GlueX data already stress-test, is gluonic structure; and what will be *argued from* the extractions is a ledger entry whose scheme-dependence §22.3 has already quantified.

This framework has a stake in that decade, and it is registered here so the reader can hold the paper to it. The debt D-P6-5 — the warped zero-mode profiles in the GDOS radial functions, this paper's registered owing on the proton's *spatial* readout — is, when discharged, a computation of exactly the profiles this program measures. Its first acceptance test is hereby fixed: *the computed profiles must reproduce the model-robust ordering* $r_{mass} < r_{charge}$ (Duran et al., 2023). On the D-term this framework registers no claim in either direction — a ground attractor is mechanically stable, and stability has a standard mechanical signature, but the experimental situation (Burkert et al., 2018; Kumerički, 2019) is not one any theory should lean on yet, and if a profile computation one day delivers a D-term, the lattice (Hackett et al., 2024) is the comparison of record. These are targets, not results; the framework's posture toward this experimental program is the one an honest theory wants: *exposed*.

24 The open problems, on all sides

A review that ends in applause is advertising. This one ends with the homework — the community's, and this framework's, side by side, because Q1 is only honestly answered when both lists are on the table. Seven problems, each with its current state and its owner.

OP-1 (the absolute scale). Dimensional transmutation converts "why is m_p twenty orders below the Planck mass" into "why does the coupling have the value it has at the reference scale" — and there the standard account stops, because $\alpha_s(M_Z) = 0.1180(9)$ is measured, not derived (Navas et al., 2024). The stopping point is structural, not lazy: even the celebrated ab-initio spectrum computations fix their overall scale with measured hadron masses (Dürr et al., 2008; Borsanyi et al., 2015) — ratios are computed, the scale is an input — and the emergent-hadron-mass literature states frankly that the source of the hadronic GeV "remain[s] puzzling" (Roberts et al., 2021). No account outside the present framework, to this paper's knowledge, prices the number itself. The framework's entry is §21.4: the registration $\alpha_s^{-1}(M_Z) = \pi e$ (GG-A9-SM's, at GG-A9-SM's declared grade and audit), transported by the standard machinery, prices Λ with no strong-sector measurement and lands the proton's mass at five percent, first order. Its fences are stated there and not repeated as fine print here: the claim is exactly as strong as its input's grade, and its input's grade is published.

OP-2 (the itemization). Is "how much of the mass is trace anomaly" well-posed? Ji: yes, per scheme, and worth measuring (Ji, 1995, 2021). Lorcé, Metz–Pasquini–Rodini: only two terms are invariant; the rest is convention (Lorcé, 2018; Metz et al., 2020). The 2026 all-schemes lattice computation: the entry ranges from 6% to 35% depending on the ledger (Bollweg et al., 2026). This framework's reading (§22.4): the stalemate is structural — the parts are bulk, the depth is the boundary observable — i.e. the dispute is not awaiting a winner; it is exhibiting a custody boundary. INT grade, fences stated where the reading lives.

OP-3 (experimental access). Whether threshold quarkonium data determine gluonic structure model-independently is open; the experiments' own papers hedge it honestly (GlueX Collaboration, 2023; Duran et al., 2023), the pressure claim has a published consistent-with-zero rebuttal (Kumerički, 2019), and the EIC is the community's designed answer (Abdul Khalek et al., 2022). The framework's stake — the D-P6-5 acceptance test — is registered in §23.3.

OP-4 (the gap). Underneath every statement in this Part sits an unproven theorem: that four-dimensional Yang–Mills theory exists as a mathematical object and has a mass gap — one of the Clay Millennium Problems, and still open in the 2026 survey of record, which notes that both halves (existence and gap) remain unproven with no clear path visible (Douglas, 2026). This paper's engagement with the gap lives in Part V at the Clay register stated there, and one disambiguation belongs here: the *gap* (the lowest excitation of the pure-gauge sector) and the *depth* (the proton's mass on the $B = 1$ stratum) are different questions. Pricing the second to five percent (§21.4) neither requires nor delivers the first; conflating them flatters everyone and helps no one.

OP-5 (the pure number). Granted Λ by measurement, the ratio $m_p/\Lambda^{(3)}_{\overline{\mathrm{MS}}} \approx 938/340 \approx 2.76$ has no analytic derivation anywhere in physics — there is not even a controversy about it, which is its own measure of how open it is. Only the lattice computes it (Dürr et al., 2008). The framework's entry is the program of §24.1 below — registered, two-legged, and falsifiable at its first step.

OP-6 (the sigma-term tension). The Higgs-coupled condensate share of the nucleon's mass is itself in dispute at the 2.4σ level: standard lattice analyses give $\sigma_{\pi N} \approx 42$–$44$ MeV (Gupta et al., 2021; Agadjanov et al., 2023), phenomenology from pion–nucleon scattering gives ≈ 59 MeV, and the same lattice data move by 17.7 MeV — two percent of the proton's mass — depending on how $N\pi$ excited states are treated (Gupta et al., 2021). This framework *cannot help*, and says so with its reasons: the tension is a lattice-systematics question inside boundary-EFT chiral dynamics, a regime in which this framework defers to the standard theory by construction. What the framework can state is robustness: no number registered anywhere in this paper moves, whichever value wins.

OP-7 (the dichotomy). The same dynamics that makes the proton heavy makes the pion light: the pion is the pseudo-Goldstone mode of chiral symmetry, massless in the chiral limit, and the emergent-hadron-mass program is organized around precisely this pairing (Roberts et al., 2021). Nothing here is a puzzle for this framework to solve; it is a structure to inherit intact, and the framework inherits it: chiral dynamics on the boundary is standard physics. The basin language does offer a clean translation — the proton's mass is the *depth* of a basin, while the pion is a *phase direction* of the vacuum, and depths are priced while phase directions cost nothing by symmetry — but this paper records that sentence as a translation, not a result. Where this framework does own a Goldstone computation, it has already published it: the flux tube's transverse phase modes, counted by the Lüscher coefficient in §42, are the cohort's one delivered quantitative statement about string phase modes, and they came out right.

24.1 The pure-number program: the last import, named

One import stands between the closure of §21.4 and a proton mass priced from the Planck scale end to end: the lattice's pure number (14). This subsection names the program that would derive it — registered here so that its success or failure is checkable against a written record.

The number factorizes through the string tension σ, the measured stiffness of Part V's flux tube:

$$\frac{m_p}{\Lambda} = \underbrace{\frac{m_p}{\sqrt{\sigma}}}_{2.13} \times \underbrace{\sqrt{\frac{\sigma}{\Lambda^2}}}_{\sqrt{1.675}=1.294} = 2.76, \qquad (21)$$

each factor at today's world values ($\sqrt{\sigma} \approx 440$ MeV, $\Lambda^{(3)}_{\overline{\mathrm{MS}}} \approx 340$ MeV; the identity is arithmetic, verified, and scheme-stamped by its ingredients). The factorization is not decoration; it splits the problem along the framework's own grain:

Leg 1 — σ/Λ^2: already registered. The dimensionless ratio of the flux tube's tension to the transmutation scale is precisely the "decisive number" of Part V: the wall computation of D-P6-4(c), with its target (1.67) and its honest kill window ($[1.42, 1.93]$) already printed in §43. Nothing new is claimed here; the existing registration is simply recognized as the harder half of OP-5.

Leg 2 — $m_p/\sqrt{\sigma}$: basin spectroscopy. The ratio of the ground attractor's depth to its own wall's tension. Today it is a lattice import (2.13). A GDOS computation of it would be ground-state spectroscopy of the basin in the same GFF normalization the wall computation already requires — the two legs share their hardest ingredient, which is why they constitute one program rather than two wishes.

If both legs land, the chain of §21.4 loses its one import, and the proton's mass is priced from the Planck scale with no experimental input at any link — the strongest statement this framework could ever make about Q1, and one it does *not* make today. If leg 1 lands outside its window, the wall reading dies exactly as registered in Part V, and this program dies with it. That is the correct shape for a promise: dated, numbered, and mortal.

24.2 The scoreboard

The depth is priced, itemization and all; the seven problems are on the table with their owners named. What remains of Q1–Q2's ledger is the charge — the twenty-one-digit half of the theorem — and that is where the Part goes next.

25 The exact charge: one codebook, read twice

Q2 looks like a second mystery; it is the same theorem read along the other winding.

Table 5: The seven open problems of the proton's mass, scored for both sides. Grades in the right column are this paper's standard vocabulary; "cannot help" is recorded as a grade because a framework that cannot say it should not be trusted when it says anything else.

Problem	**Community status**	**This framework's entry**	**Grade**
OP-1 scale	input everywhere; ratios only	πe chain $\Rightarrow m_p$ to 5%, no strong-sector input (§21.4)	derived, 1st order, fenced
OP-2 itemization	30-year dispute; scheme-dependence measured in 2026	custody: parts are bulk, depth is the observable (§22.4)	INT
OP-3 access	model-mediated; experiments hedge	D-P6-5 acceptance test: $r_{\text{mass}} < r_{\text{charge}}$ (§23.3)	target
OP-4 gap	Clay problem; open (2026 survey)	conditional theorem behind a named gap hypothesis (Part V)	conditional
OP-5 pure number	no analytic derivation exists	two-leg program via (21); kill window printed	program
OP-6 sigma term	2.4σ lattice–phenomenology tension	none — boundary-EFT custody; robustness verified	cannot help
OP-7 dichotomy	organizing puzzle of the EHM program	inherited intact; basin translation; Lüscher adjacency	inherited

25.1 The embedding does the arithmetic

In the descent (4), hypercharge is not assignable — it is the surviving diagonal of SU(5), fixed up to normalization by the embedding itself. On the fundamental,

$$Y \;=\; \text{diag}\Big(-\tfrac{1}{3},\, -\tfrac{1}{3},\, -\tfrac{1}{3},\, +\tfrac{1}{2},\, +\tfrac{1}{2}\Big)\,, \tag{22}$$

the unique traceless generator commuting with $\text{SU}(3)_C \times \text{SU}(2)_L$ — tracelessness is the whole constraint, and it is why lepton and quark charges cannot float independently: they are entries of one matrix that must sum to zero. Electric charge is then $Q = T_3 + Y$, and the family table falls out:

$$\begin{aligned} &\text{from } \mathbf{\overline{5}}: \quad Q(d^c) = 0 + \tfrac{1}{3} = +\tfrac{1}{3}, \quad Q(\nu) = +\tfrac{1}{2} - \tfrac{1}{2} = 0, \quad Q(e^-) = -\tfrac{1}{2} - \tfrac{1}{2} = -1; \\ &\text{from } \mathbf{10}: \quad Q(u) = +\tfrac{1}{2} + \tfrac{1}{6} = +\tfrac{2}{3}, \quad Q(d) = -\tfrac{1}{2} + \tfrac{1}{6} = -\tfrac{1}{3}, \quad Q(e^c) = 0 + 1 = +1. \end{aligned} \tag{23}$$

The proton assembles as

$$Q(p) \;=\; Q(uud) \;=\; \tfrac{2}{3} + \tfrac{2}{3} - \tfrac{1}{3} \;=\; +1 \;=\; -\,Q(e^-), \tag{24}$$

and the equality on the right is not a coincidence to be protected — it is the same diagonal matrix (22) evaluated on two of its own blocks. Hydrogen is neutral for the same reason a column of a magic square hits the magic number: by construction of the square. The anomaly conditions that the Standard Model checks after the fact — four independent sums per family that "have no right to work" — hold here packet by packet as bookkeeping identities of the same embedding (Part II; the sums themselves are walked in the home paper's course).

25.2 Why the charge cannot drift

Exactness of the *value* is algebra; exactness over *time and place* needs one more ingredient, and it is the Part's title concept again. On the boundary, electric charge is the winding number of the readout on the electromagnetic fiber — the sister paper's Part on why the electron moves derived this, and Part VI will install the baryonic twin of it. Windings are integers (in units of the fiber's quantum): they cannot drift, run, age, or depend on altitude, because there is no continuum between 1 and $1 + \epsilon$ for a winding to occupy. A proton at the bottom of a mine in 1985 and a proton in a beam halo in 2040 read out the same winding for the same reason a knot tied twice is not tied 2.001 times.

25.3 The experimental face

The neutrality of bulk matter is among the most precise null results in science: the charge per hydrogen molecule is bounded at the level of $10^{-21}\,e$ (Bressi et al., 2011), and antihydrogen's charge is bounded at 0.71 parts per billion (Ahmadi et al., 2016) — the conjugate readout holding to its winding with the same rigidity. Within this framework these are not two lucky cancellations but one algebraic identity (24) plus one topological rigidity (§25.2); the corresponding kills are registered as part of F-P6-4's family: a confirmed non-zero charge of hydrogen, a drift of $Q(p)/|Q(e)|$ from unity at any epoch, or an antihydrogen charge anomaly each falsifies the embedding-plus-winding reading outright.

26 One theorem, two sharpnesses — and the identity corollary

Assemble the Part. The mass is sharp because the proton is the GGA of its stratum: zero width is the empty exit-channel set, the value is the basin's depth, priced by transmutation from a derived coupling, and no per-object freedom exists (T-P6-3). The charge is sharp because it is a winding evaluated on the embedding's diagonal: quantized in value, topologically rigid in time. Both sharpnesses are the absence of continuum where the century expected mechanism — there is nothing to adjust in a floor, and nothing to drift in an integer. That is the sense, made precise, in which Q1 and Q2 are one theorem: *the proton's two exact numbers are the two conserved coordinates of its stratum, read at the stratum's unique terminal point.*

The identity corollary. It follows — exactly as in the sister paper, and the corollary deserves its lonely paragraph — that protons in causally disconnected regions of the universe are identical, not because a signal synchronized them but because both read the same basin of the same landscape: uniqueness is a property of the functional, not an agreement among particles. When Hyper-Kamiokande's photomultipliers watch 6×10^{34} protons, they are not watching a population; they are watching one mathematical object, massively attended.

27 What would change our minds: the Part's falsifier faces

Pre-registered in §5, sharpened here with the Part's machinery on the table.

A measured proton width. Any nonzero total width — equivalently any decay, F-P6-1 — contradicts terminality directly. The stability leg is Part VI's; but note that even a B-conserving width (some exotic $p \to$ lighter-B=1 channel) would separately kill legs (i)–(ii) by exhibiting a lower floor. There is no such channel in eighty years of spectroscopy.

A second zero-width baryon. A degenerate partner — two exact states at 938 — kills uniqueness (leg ii) and with it the identity corollary. The excited rungs all carry widths; finding one that does not, other than the bound-neutron case Part VIII prices, is a kill.

A proton mass or charge anomaly. Any environmental, epochal, or object-to-object variation of m_p or $Q(p)$ — including through the antiproton mirror at BASE's sixteen parts per trillion (Borchert et al., 2022) and the antihydrogen bound (Ahmadi et al., 2016) — contradicts leg (iv) and §25.2. The precision frontier here is not confirming this paper; it is holding a loaded gun to it, which is exactly where a framework wants its guns.

The coupling registration. If the strong-coupling world average were to move several standard deviations from $1/\pi e$, the pricing story of §21 loses its framework input and reverts to measured-input transmutation — not a kill of T-P6-3, whose legs are independent of the registration, but a registered wound to GG-A9-SM's ledger, and this paper says so plainly rather than decoupling itself after the fact.

28 Status ledger of the Part

The Part closes where it opened, with the reader in the tank. The sharp mass you sum over and the exact charge your Cherenkov cones reconstruct are not two conveniences of nature; they are the two conserved coordinates of the ground attractor, and the silence your experiment keeps recording is the third face of the same object — the one Part VI now derives.

Table 6: Status ledger of Part III. Every claim of the Part with its grade and its fences. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it. Part III's ledger is the longest of the nine, because the floor theorem is proved in four legs and each leg carries its own fence.

Claim	**Grade**	**Fences / notes**
T-P6-3 leg (i): existence of the floor	D	On the GDOS tower + action boundedness imports; lattice confirmation independent.
T-P6-3 leg (ii): uniqueness	D(c)	Conditional on the completeness of the constitutional label inventory (GG-A1-Constitution); fence named here, carried to the D-P6 registry.
T-P6-3 leg (iii): zero width	D(c)	The B-conservation leg at Part VI's grade (H3 + R2 + R3); all other channels closed unconditionally by legs (i)–(ii).
T-P6-3 leg (iv): identity of readouts	D	Given (i)–(iii); sister-paper argument transposed.
Transmutation mechanism (10)–(11)	D	Standard physics, cited; walked in Appendix A.
Coupling registration $\alpha_s^{-1}(M_Z) = \pi e$	D(c)	GG-A9-SM's, at GG-A9-SM's declared register (first order + QD completion); deviation -0.76%, pull -0.70 stated.
One-loop walk values (13)	D	Exact consequences of the above; one-loop understatement of Λ declared, four-loop world value quoted beside it.
Pure number $m_p/\Lambda \approx 2.8$	D	Lattice, cited; no framework content claimed.
Charge table (22)–(24)	D	Embedding algebra; anomaly identities per packet (GG-A9-SM).
Charge rigidity as winding	D(c)	On the sister paper's fiber reading (its grade) and Part VI's baryonic twin.

Part IV
The Label That Would Not Decompose

Spin 1/2 as the basin's readout label (Q3)

The next three Parts read the one fact of Part III from three more sides, and the first side is the strangest: a property so rigid that no experiment has ever budged it, sitting on top of constituents whose own contributions famously refuse to add up to it. This is the shortest of the question Parts, and its lesson — that a label is not a sum — will be used by every Part that follows.

29 A crisis, told properly

Every so often physics runs an experiment whose result is so uncomfortable that the community names it a *crisis* rather than a discovery. It is worth pausing on what an honor that is: most measurements merely narrow an error bar, and only a handful per century catch the whole field holding a wrong picture. The proton's spin owns one of them, and this Part will argue that the crisis was, from the first day, a custody dispute — the right number filed under the wrong owner.

The wrong picture was beautiful, which is why everyone held it. In the quark model that organized the 1960s, the proton is three quarks in an S-wave: no orbital motion, so the proton's spin $\frac{1}{2}$ must be assembled from the three quark spins — two up, one down, suitably arranged. The picture predicts, through the same wavefunctions that give the famous magnetic-moment ratio $\mu_p/\mu_n \approx -\frac{3}{2}$ (one of the quark model's genuine triumphs), that the quark spins carry essentially *all* of the proton's spin: $\Delta\Sigma \approx 1$ in the naive counting, softening to roughly two thirds once relativistic motion is allowed for. Reasonable people differed about the correction; nobody doubted the ownership.

Then the European Muon Collaboration measured it (Ashman et al., 1988). Deep-inelastic scattering of polarized muons on polarized protons reads out, through the structure function g_1, the fraction of the proton's spin carried by the spins of its quarks and antiquarks. The 1988 answer was $\Delta\Sigma = 0.12 \pm 0.09 \pm 0.14$ — consistent, within errors, with the quarks carrying *none* of it. The follow-up decades — SMC, HERMES, COMPASS, the RHIC spin program, JLab — steadied the value without rescuing the picture: today's global fits put

$$\Delta\Sigma \;\approx\; 0.25\text{–}0.35 \qquad (\text{at } Q^2 \text{ of a few GeV}^2), \tag{25}$$

roughly *one third* of the proton's spin in the quark spins, with the gluon polarization now measured to be real and positive over the accessible momentum range (de Florian et al., 2014) and the remainder assigned to orbital motion nobody has yet directly weighed. The S-wave picture — no orbital angular momentum at all — was not corrected; it was demolished.

For the reader in the tank. You inherited this story whether you know it or not. The polarized beams at RHIC that measured ΔG, the JLab halls that walked g_1 to low Q^2, and the Electron–Ion Collider now rising at Brookhaven (Accardi et al., 2016) — whose first physics case, printed in its white paper, is precisely "how does the proton's spin arise" — are the same lineage of machines as your tank: instruments built because the proton declined to be simple. When the EIC data arrive during your career, this Part is a pre-registered prediction about what they will and will not change.

30 The bookkeeping, done honestly

Before the framework says its piece, the standard accounting deserves to be laid out with care, because it is correct — and because *where* it is correct is the whole point.
Angular momentum is conserved and the proton's total is exact:

$$J_p \;=\; \tfrac{1}{2}. \tag{26}$$

The question is how to write $\frac{1}{2}$ as a sum of parts. Two canonical ledgers exist. The *Jaffe–Manohar* decomposition (Jaffe and Manohar, 1990),

$$\tfrac{1}{2} \;=\; \tfrac{1}{2}\,\Delta\Sigma \;+\; \Delta G \;+\; L_q \;+\; L_g, \tag{27}$$

splits the total into quark spin, gluon spin, and the orbital angular momenta of each — a partonic ledger, natural in the infinite-momentum frame and light-cone gauge, whose entries are what polarized deep-inelastic scattering actually measures. The *Ji* decomposition (Ji, 1997),

$$\tfrac{1}{2} \;=\; J_q + J_g \;=\; \left(\tfrac{1}{2}\,\Delta\Sigma + L_q^{\mathrm{Ji}}\right) + J_g, \tag{28}$$

is gauge-invariant and frame-independent, its entries reachable through generalized parton distributions — but its orbital term differs from Jaffe–Manohar's by a genuine, calculable amount (the difference is sometimes called the potential angular momentum: torque the color field exerts while you carve the proton into named pieces). Both ledgers are internally exact. They disagree with *each other* about how much orbital angular momentum the quarks "have," and there is no experiment, even in principle, that declares one attribution the truth of the matter — each is the truth *of its convention*.
One more honest wrinkle, because it teaches the lesson in miniature: the quantity the EMC measured is not even purely $\Delta\Sigma$. Through the axial anomaly, the measured singlet combination is contaminated by the gluon polarization,

$$a_0 \;=\; \Delta\Sigma \;-\; \frac{3\,\alpha_s}{2\pi}\,\Delta G, \tag{29}$$

a shift worth about 0.07 for $\Delta G \approx 0.4$ at $\alpha_s \approx 0.35$ (Appendix B walks the arithmetic). Even the crispest entry in the ledger, read at experimental precision, turns out to be a convention-laden mixture of two others. The parts blur into each other. The total never blurs at all.
Hold those two sentences side by side, because they are the data of Q3 stated exactly: *every*

decomposition of the proton's spin is scheme-dependent, frame-dependent, and anomaly-contaminated; the total is exactly $\frac{1}{2}$, always, everywhere, for every proton ever measured. A quantity and its parts are behaving as if they belong to different categories of fact. The framework's answer is that they do.

31 The label and the ledger: the custody reading

Recall the division of custody that organized Part III: the bulk owns the storm; the boundary owns the stationary readout. Apply it to angular momentum and the crisis dissolves — not into a calculation (this Part claims none) but into a category distinction that the calculations above have been exhibiting all along.

The total is a label. On the boundary, the proton is a readout of the ground attractor, and a readout does not have angular momentum the way a flywheel does — it *transforms* under rotations, and the transformation law is one of the finitely many irreducible options the rotation group offers: $j = 0, \frac{1}{2}, 1, \ldots$ The basin presents the spinor option, $j = \frac{1}{2}$ — Part II inherited the chirality projection that makes the boundary's matter spinorial, and Part IV's owed item (below) is the derivation that the baryonic basin's readout sits in that representation. A representation label is not a sum of contributions; it is a discrete answer to the question *how does this object respond to being turned.* It can no more be 51% of $\frac{1}{2}$ than a knot can be tied 2.001 times — the same rigidity that guarded the charge in §25.2, wearing its rotational face.

The shares are a ledger of the bulk. The storm — sea quarks, gluon flux, orbital swirl — carries angular momentum in the ordinary dynamical sense, and the partonic ledgers (27)–(28) are legitimate, measurable bookkeepings of it. But the storm is bulk structure, and carving one bulk quantity into named parts requires choosing a frame, a gauge, a factorization scheme — which is exactly why every such carving is convention-dependent and no experiment can crown one of them. The shares are real the way departmental budgets are real: exact within an accounting convention, meaningless across conventions, and never the explanation of why the company's total is what it is.

The crisis, re-read. The 1987 shock was the discovery that the label does not reduce to the most natural-looking ledger line. Within this framework that is not a paradox to repair but the *expected* relationship between a boundary label and bulk bookkeeping: the label answers to representation theory; the ledger answers to dynamics; and the sum rules (27)–(28) are the consistency condition connecting them — angular momentum conservation guarantees the ledger totals the label, in every convention, while no convention's line-items are forced. The proton's spin was never missing. It was filed under the object, and the century went looking for it in the objects' parts.

Physics intuition: the symphony and the seats. Ask "which musicians carry the key of E minor?" and the orchestra will stare back: the key is a property of the piece, not a sum over seats, even though nothing but the seats is producing the sound. The parton ledgers are the seating chart of the proton's angular momentum — genuinely informative, endlessly refinable, and category-mistaken as an answer to why the piece is in E minor. The EMC did not lose the proton's spin; it discovered that the piece's key is not stored in any section of the orchestra.

32 What this Part claims, what it owes, and what would kill it

This Part is deliberately the most modest in the paper, and says so in its ledger. The custody reading is an *interpretation* — graded INT, named as such — whose value is that it turns a forty-year "crisis" into the expected behavior of a two-level structure the rest of the paper derives for independent reasons. What would promote it to a theorem is owed and registered: **D-P6-3**, the spinor-level derivation that the terminal basin's boundary readout carries $j = \frac{1}{2}$ — the baryonic face of the same debt the sister paper carries as D-P3-4, and the two will be discharged by one computation when the spinor thread runs (the shared machinery is already noted in both registries).
The falsifier faces, stated with the honesty the softness of an INT grade demands:

The hard face (shared with rotation invariance). Any measured deviation of the proton's total spin from exactly $\frac{1}{2}$ — a fifth Stern–Gerlach beam, an anomalous multiplet — kills the label reading and a great deal else besides. This face is hard but not proprietary: its failure would wound quantum mechanics before it wounded this paper, and the ledger says so rather than claiming borrowed sharpness.

The pre-registered EIC face. As the Electron–Ion Collider closes the small-x gap, the framework expects: the ledger entries will continue to sharpen ($\Delta\Sigma$ toward the low end of (25), ΔG finite, orbital terms measurably nonzero — with today's central values, roughly 0.15 of orbital remainder in the Jaffe–Manohar ledger); the sum rules will saturate exactly, as conservation demands; and *no convention-independent decomposition will emerge.* A future theorem or measurement exhibiting a scheme-independent, experimentally-forced partition of the $\frac{1}{2}$ into parton parts would falsify the custody reading — the shares would then be boundary facts, not bulk bookkeeping, and this Part would be wrong in its central category claim. That is a real, if long-fuse, kill: the reading forbids something the standard picture merely fails to provide.

The debt face. If the D-P6-3 computation, when run, returns anything other than $j = \frac{1}{2}$ for the terminal basin's readout, the label story collapses arithmetically. A registered debt is a loaded gun by construction.

33 Status ledger of the Part

The Part hands the baton forward: the label was rigid because representation labels are; the charge was rigid because windings are; and the next Part meets the century's deepest rigidity — the quarks that cannot leave at all — where the same custody principle has its hardest and most rewarding work to do.

Table 7: Status ledger of Part IV. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it. Part IV's turns on the difference between a representation label and a bulk ledger, and the row that names it is an interpretation, not a derivation.

Claim	**Grade**	**Fences / notes**
Total $J_p = \frac{1}{2}$ exact, universal	D	Representation label of the boundary spinor readout; empirically unchallenged.
The two ledgers (27), (28) and their scheme-dependence	D	Standard physics, cited; the anomaly shift (29) walked in Appendix B.
Measured shares (25); $\Delta G > 0$	D	World data, cited; ranges quoted, not sharpened.
Custody reading (label vs. bulk ledger)	INT	Named interpretation; its forcing computation is the registered debt D-P6-3 (shared with D-P3-4).
EIC pre-registration (no convention-independent partition will emerge)	INT	The reading's genuine forbidden outcome; long fuse, honestly labeled.

Part V
Confinement and the Absent Quark

The cage measured and compared; the conditional area-law theorem; no boundary channel for color (Q4, Q5)

Part IV read the one fact of Part III from the first of three sides. This is the second, and it goes after the thing that is never there. Nobody has seen a free quark in fifty years of looking, and nobody has proved that nobody can; this Part is careful about that difference from its first page to its last. It measures the cage, states what any account of confinement has to explain, records exactly what the lattice proves as against what it computes to precision without proving, and grades the mechanisms on the market on a single scorecard with theorem-grade results only. What it offers of its own comes after all of that: a center identity, a wall on the scale axis, and an area-law theorem that is conditional, with the condition named rather than buried.

34 The problem of the century, and this Part's contract

Before the equations, the story — because the reader this paper is written for deserves to know exactly what kind of problem confinement is, and why the field speaks of it with a respect it grants nothing else in the Standard Model.

In 1964, Gell-Mann and Zweig proposed that the proton is made of three fractionally charged pieces (Gell-Mann, 1964; Zweig, 1964). The idea explained the hadron zoo overnight, and it carried a plain-sounding homework assignment: go find one. The searches began at once — oil-drop descendants hunting for a charge of $e/3$, accelerator experiments watching for a fractional track — and they have never stopped, and they have never found one. Then, in 1968, the SLAC experiments did something stranger than finding a quark: they *saw* quarks, clearly and repeatedly, rattling around *inside* the proton like loose change — while the outside world remained as quark-free as ever (Breidenbach et al., 1969). Physics had met a particle that is manifestly there and cannot be taken out. In 1973 half of the paradox dissolved: Gross, Wilczek, and Politzer showed that the color force weakens at short distances (Gross and Wilczek, 1973; Politzer, 1973), so a quark probed at close range behaves almost freely — asymptotic freedom, the discovery that made QCD credible. But the same result made the other half of the paradox sharper. A force that weakens as you zoom in must *strengthen* as you zoom out. How much? Without limit? Nobody could compute in that regime — until Wilson, in 1974, put spacetime on a lattice and showed that at strong coupling the energy between two quarks grows in proportion to the area swept between them (Wilson, 1974): the first honest calculation ever to *produce* a cage rather than assume one. Five decades of lattice computation since have turned that first glimpse into the most thoroughly measured unproven statement in physics (Bali, 2001).

Unproven — and that word has a price on it. In the year 2000, the Clay Mathematics Institute selected seven mathematical problems for the new millennium, offering a million dollars for each; alongside the Riemann Hypothesis sits "Yang–Mills existence and mass gap" (Jaffe and Witten, 2000). Stripped of formality, it asks two things. *Build it*: show that the theory of the color force exists as a mathematically complete object in continuous spacetime — not on a grid, not to some order of approximation, but exactly. *Then weigh it*: prove that the lightest thing the gluon field can make weighs something rather than nothing. (Experimentally there is no suspense about the second part: the lattice puts the lightest pure-glue state, the scalar glueball, at 1.71 GeV (Morningstar and Peardon, 1999). The million dollars is not for knowing the number; it is for *proving* a number exists.)

Why is that so hard, when the lattice computes these things routinely? In plain language: essentially every proof technique in quantum field theory lives where the coupling is weak, because weak coupling means you are making small corrections to a problem you can solve exactly. Confinement lives where the coupling is strong — where there is no solvable problem nearby to correct, and the phenomenon itself is the failure of every approximation you own. Wilson's strong-coupling result does not rescue the situation, for a subtle reason worth stating once: his derivation works on a coarse lattice, but the real world is the limit of a finer and finer one, and between the coarse regime and the continuum the mathematics changes character in a way that breaks the argument's continuation. Computing across that divide is easy; proving across it has defeated everyone for fifty years. And one more trap awaits the unwary, which this Part will step around carefully: the two halves of the Clay problem are not the same thing. A theory can have a mass gap and still fail to confine — give the Standard Model's Higgs boson color, and you would get a world where every excitation weighs something yet quarks stroll out of protons freely. The gap does not buy the cage. In four dimensions, nothing does; that, in one sentence, is why the problem has a price on its head.

So much for the story; now the contract, because every claim in this Part stands behind it. *Confinement is not a proven property of quantum chromodynamics, and this paper claims no continuum proof.* What this Part does claim, each piece at its stated grade, is exactly three things:

Answered outright. The *existence* question — is the free quark a possible object at all? — is answered by a corollary of Part VI's lock (C-P6-1, §44): the free quark is not expensive but meaningless, at the lock's stated conditional grade.

A theorem, given the gap. The *cage* itself — the linearly rising cost of separation — is derived as a theorem conditional on one named hypothesis: that the color vacuum has a gap (T-P6-4, §41). The gap plays for this framework exactly the role it plays for the Clay problem: the hard part, left visibly open.

Not claimed. The gap itself; the continuum construction; anything the Millennium Problem asks. The paper's precise coordinates relative to that problem are stated in §47, including its declination, in writing, of any claim on it.

A paper that blurred this contract would be borrowing rigor it has not earned; a reviewer should test every sentence below against it. With the contract signed, we can now walk the territory, which is some of the most beautiful in physics — and we walk it the long way: the measured facts first, then the field's own maps, then this framework's additions, graded.

35 The cage, measured

Start with what the cage *feels* like, because the numbers are wonderful and too few students ever meet them.

Between a static quark and antiquark, the chromodynamic potential takes the form the quarkonium spectra and the lattice agree on (Bali, 2001):

$$V(r) \;\simeq\; -\frac{4}{3}\frac{\alpha_s}{r} \;+\; \sigma r, \tag{30}$$

a Coulombic term that dominates up close — asymptotic freedom's signature, the regime where the SLAC quarks scattered as if free — and a *linearly rising* term that takes over farther out. The two terms trade places at a radius the reader can compute in one line: with $\alpha_s \approx 0.3$ at these scales, the magnitudes are equal at $r \approx 0.28$ fm, and by one femtometer the string term outweighs the Coulomb term six to one. The coefficient of the linear term, the string tension, is

$$\sigma \;\approx\; (440\ \text{MeV})^2 \;=\; 0.98\ \text{GeV/fm}. \tag{31}$$

Convert that into units a human can feel (Appendix C does the arithmetic): the flux tube between a separating quark pair pulls with a constant force of about 1.6×10^5 newtons — *sixteen tonnes-force* — independent of distance. Two subatomic points, connected by a cable of pure gluon field a fraction of a femtometer thick, tugging with the weight of a loaded truck, forever. Gravity weakens with distance; electromagnetism weakens with distance; the color string does not weaken at all.

The tension is measured three independent ways, and their agreement is the first quantitative fact the Part asks the reader to hold. The lattice extracts (31) from the static potential directly. The hadron spectrum extracts it from the Regge trajectories: a spinning relativistic string of tension σ has $J = \alpha' M^2 + \text{const}$ with $\alpha' = 1/(2\pi\sigma)$, and the measured light-meson slope $\alpha' \approx 0.9\ \text{GeV}^{-2}$ inverts to $\sqrt{\sigma} = 421$ MeV — five percent from the lattice, from a one-line classical model (Appendix C). And the quarkonium level spacings fit the same Cornell form (30). Three roads, one tension: the hadrons have been telling us they are strings-with-endpoints since the 1960s.

The string is not a cartoon; the lattice has measured its *quantum vibrations*. A flux tube of length r whose only massless excitations are its two transverse waves must carry a universal correction to its energy,

$$V(r) \;\supset\; -\frac{\pi}{12}\frac{\hbar c}{r} \;=\; -51.7\ \text{MeV} \times \frac{1\ \text{fm}}{r}, \tag{32}$$

the Lüscher term (Lüscher et al., 1980) — universal because it counts nothing but the number of directions the string can wobble in, $-(D_\perp)\pi/24$ with $D_\perp = 2$. The lattice confirms the coefficient at the few-percent level. Hold on to that innocent-looking statement: in §42 it becomes a precision test of this framework's deepest structural commitment, and the framework passes it.

Except that nature is cleverer than an infinite bill, and the actual endgame is more instructive than the infinity. Stretch the string and the stored energy grows at 0.98 GeV per femtometer; at the measured breaking radius $r_b \approx 1.24$ fm (Bali et al., 2005) the account reads $\sigma r_b \approx 1.22$ GeV — enough to pay for a light quark–antiquark pair — and the string *snaps by budding new endpoints*: the lattice sees the static potential flatten there, the flux tube giving way to two heavy-light hadrons. Pull on a quark and you do not get a free quark at any cost — you get two hadrons where there was one. The rubber band, cut, grows a fresh end on each piece. This is why eighty years of trying has never liberated a quark *even in principle within the dynamics*: the vacuum itself is a pair-production machine that re-dresses every color charge faster than any apparatus can expose one.

Two more measured facts complete the dossier, and both will matter later. First, *Casimir scaling*: at intermediate distances the tension binding a pair of adjoint sources is larger than the fundamental tension by the ratio of their Casimirs, $C_{\text{adj}}/C_F = 9/4$, confirmed on the lattice at the few-percent level — yet *asymptotically* the adjoint string breaks (two gluons pop from the vacuum and screen the sources) while the fundamental string, below r_b's pair threshold, never loses its tension to screening at all. Who is permanently confined is decided not by the Casimir but by a coarser label — and §39 names it. Second, the heat: hadronic matter crosses over into a quark–gluon plasma at $T_c = 156.5 \pm 1.5$ MeV (Bazavov et al., 2019) — a smooth crossover in physical QCD, but a genuine *first-order* transition at $T_c \approx 270$ MeV in the quarkless pure-gauge theory (Greensite, 2011), a distinction that looks technical and is anything but: §39 will show the same coarse label controlling it.

Figure 12 assembles the whole measured cage in one drawing.

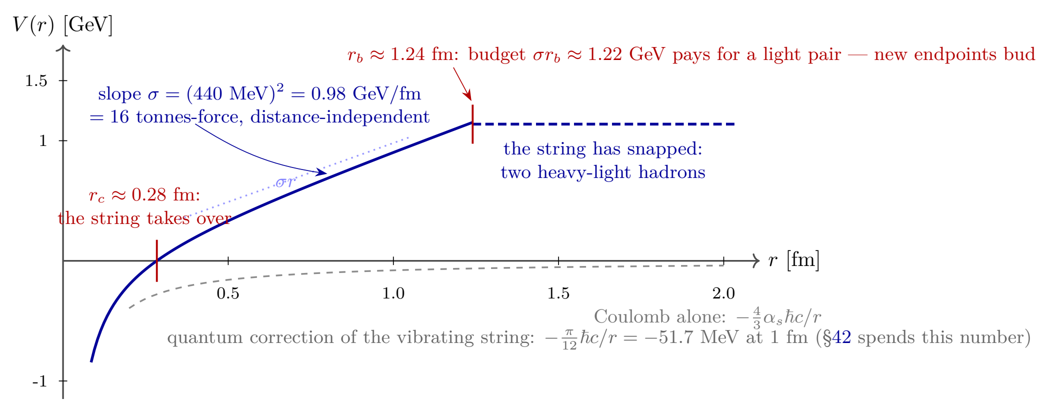


Figure 12: The measured cage in one drawing. The static potential (30) runs Coulombic below $r_c \approx 0.28$ fm (asymptotic freedom's regime), rises linearly at $\sigma = 0.98$ GeV/fm — sixteen tonnes-force, at any distance — and terminates at $r_b \approx 1.24$ fm (Bali et al., 2005), where the stored 1.22 GeV pays for a light quark–antiquark pair and the string snaps by budding new endpoints: the potential flattens into two heavy-light hadrons, and no free quark appears at any price. The vibrating string carries the universal Lüscher correction (32), whose coefficient counts the tube's transverse directions — a number this Part will convert into a test of the framework (§42).

For the reader in the tank. Your detector medium is this physics, industrialized. Every proton in Super-Kamiokande's water and every argon nucleus in DUNE is a bag of confined color; every pion your reconstruction fits was born in a string break; and when a GeV-scale neutrino shatters a nucleon in your fiducial volume, the debris reaching your photomultipliers has been laundered, without exception, into color singlets before it traveled a single fermi. Confinement is not an exotic topic from a theory course; it is the reason your event displays contain tracks at all.

36 What must be explained: five claims, one scorecard

Rigor about confinement begins with an observation the literature routinely skips: "explain confinement" bundles five separable claims, and different programs prove different subsets. This Part will keep the five apart by name. A homely comparison may help before the list: "why can't I have just the north pole of a magnet?" also bundles distinct questions — whether a lone pole is a possible object, what it would cost to make one, and why cutting the bar in half just hands you two smaller magnets. Confinement is that puzzle with the stakes raised, and the half-a-magnet experience even has its exact analogue here: cut the color string and you get two hadrons, never a free end.

(K) Kinematic absence. No asymptotic state carries fractional color charge — the *existence* question. Q5 as asked.

(L) Linearity. $V(r) = \sigma r$ at intermediate distances; equivalently, the Wilson loop obeys an area law; a flux tube that does not spread.

(B) Breaking and screening. With dynamical quarks the string breaks at r_b and the potential saturates — yet (K) survives. Any account of (L) must survive (B): physical confinement is *not* an infinite potential; it is (K) enforced through (L) plus (B).

(T) Thermal structure. Pure gauge theory: a first-order transition at $\approx$ 270 MeV. Physical QCD: an analytic crossover at 156.5 MeV — and even above it, (K) holds for every readout ever recorded (§46).

(G) The gap. The color-neutral spectrum starts at $\Delta \approx 1.71$ GeV $= 3.9\sqrt{\sigma}$ (pure gauge), not at zero — the Clay half (Jaffe and Witten, 2000).

The scorecard the century hands us, stated once: *(L), (B), (T), and (G) are computed facts and proven theorems nowhere; (K) was never even formulated as a separate question* — the standard account has no language in which "the free quark does not exist" differs from "the free quark is prohibitively expensive." This framework's contribution, graded piece by piece below: (K) is answered outright at the lock's grade; (L) becomes a theorem given one named hypothesis; (B) and (T) are carried consistently; (G) remains the open core, in this framework as in mathematics — and the Part will say exactly where it lives here.

37 What the lattice actually proves

One paragraph first on what "the lattice" actually is, for the reader who has met the word but never the method. Lattice QCD replaces continuous spacetime with a four-dimensional grid of points —

typically a fraction of a tenth of a femtometer apart — on which the quark and gluon fields live like values in an enormous spreadsheet. On a grid, the theory's central quantity (the sum over all field histories) becomes a finite, if astronomical, integral, and supercomputers evaluate it by statistical sampling. The result is best thought of as a *numerical experiment performed on the theory itself*: no approximation in the physics, only statistical and grid-spacing errors, both controllable and both routinely controlled. When this paper says "the lattice measures," it means exactly that.

Because this paper's own claims lean on lattice values, the reader deserves one honest page on what the lattice *proves*, as opposed to computes; the distinction is the difference between the Clay problem being open and being settled, and it is often blurred.

What is proven, theorem-grade: on a spacetime lattice at strong bare coupling, the Wilson loop obeys an area law — Wilson's original character expansion (Wilson, 1974) establishes it analytically, confinement included, in that limit. The lattice theory itself exists rigorously at any finite spacing: it is an ordinary statistical system with a positive measure. These are real theorems and the foundation of everything else.

What is computed, superbly, but not proven: everything at *physical* coupling. The continuum limit requires the bare coupling to run to zero (asymptotic freedom read backwards), and the strong-coupling expansion does not reach there — it is separated from the continuum by a known non-analyticity (the roughening transition), so the analytic area law cannot simply be continued across. What five decades of simulation deliver instead is a numerical demonstration of extraordinary quality: the static potential (30) with its measured tension, the Lüscher coefficient, Casimir scaling, string breaking at r_b, the glueball spectrum with its 1.71 GeV gap, and the thermal structure of (T) — all with controlled extrapolations and no sign, ever, of the picture failing. In the useful phrase of the field's own standard monograph (Greensite, 2011), the lattice has turned confinement from a conjecture into a *measured property whose proof is missing*. The Clay problem is precisely the missing proof: construct the continuum theory and establish the gap. No simulation, however converged, closes it — and nothing in this Part pretends otherwise.

The reader should also hear the one methodological note the lattice community would insist on: modern machine-assisted sampling accelerates these computations but changes nothing in the theorem landscape; the gap between computed and proven is conceptual, not computational.

38 The mechanisms on the market

Between the lattice's facts and a continuum proof stands half a century of proposed *mechanisms* — candidate answers to "what does the confining?" This section walks the five serious ones, because the framework's own answer (§§39–41) belongs to a definite family among them and the reader should see the family tree. Five short portraits follow, each ending with what the idea explains and what it leaves open; a reader in a hurry can take Table 8 and move on, and a reader who stays will find that each portrait is one physical picture, not a formalism.

The dual superconductor. The oldest and most influential picture (Mandelstam, 1976): the QCD vacuum is a condensate of chromo-*magnetic* monopoles, and just as an ordinary superconductor squeezes magnetic flux into Abrikosov vortices, the dual condensate squeezes chromo-*electric* flux between color charges into a tube — linearity (L) falls out at once, since a tube of fixed cross-section costs energy in proportion to its length. Lattice support is substantial: in simulations that first isolate the theory's monopole content by a suitable gauge choice, the monopole currents alone account for $\sim 90\%$ of the string tension. What the picture never settled is which monopoles — the projection that defines them is gauge-dependent — and it has no independent answer to (K): the tube explains the price of separation, not the non-existence of the destination.

Center vortices. The second great picture ('t Hooft, 1978) locates the confining disorder in percolating tubes of quantized *center* flux: closed surfaces carrying flux valued in $\mathbb{Z}_3$, the center of the gauge group. A large Wilson loop picks up a center phase for each vortex it links; a percolating vortex ensemble randomizes those phases; the average falls off with the *area* — (L) again, now from the center's discreteness. The lattice evidence here is the sharpest of all: identify the vortices in a configuration and *remove them by hand*, and the string tension vanishes — and, remarkably, the chiral condensate vanishes with it (de Forcrand and D'Elia, 1999), as if one structure carried both confinement and chiral symmetry breaking. Hold the thought that the operative group is $\mathbb{Z}_3$; §39 is about nothing else.

Gribov–Zwanziger, and the functional methods. A third family locates confinement in the geometry of gauge-field configuration space (the Gribov horizon suppressing infrared gluons) and in the infrared behavior of exact functional hierarchies. These programs supply necessary conditions, infrared propagator structure, and valuable consistency checks; truncation control keeps them short of a theorem, and the Part records them for completeness rather than leaning on them.

Seiberg–Witten: the one true theorem, in the wrong theory. In $\mathcal{N} = 2$ supersymmetric Yang–Mills softly broken to $\mathcal{N} = 1$, monopole condensation and the dual Meissner effect are not a picture but a *derivation* (Seiberg and Witten, 1994): the low-energy theory is solved exactly, the monopole condenses, and confinement with a mass gap follows as mathematics. It remains the only four-dimensional gauge theory in which the cage is a theorem — and it is not QCD: the matter content, the supersymmetry, and even the resulting string (whose tension does not Casimir-scale) are all wrong for our world. Its lesson is nonetheless the most important on this list: *confinement becomes provable exactly when the theory contains a rigid structure — there, the Seiberg–Witten curve — that forces the condensation.* The question for any framework is what plays that rigid role.

Holography. In the strong-coupling, large-N cousins of QCD accessible through gauge–gravity duality (Maldacena, 1998), the Wilson loop is computed by a string worldsheet sagging into a warped fifth dimension; in confining backgrounds the geometry ends at an infrared wall, the worldsheet drapes along it, and the area law *follows from the geometry* — linearity as a theorem, for those cousins. The mechanism is worth stating in one sentence because this framework will realize a cognate of it with different machinery and no strings attached, literally: a scale direction with an infrared end converts confinement from dynamics into geography (§40).

Table 8: The mechanisms on the market, honestly graded. "Proves" records theorem-grade results only. The five claims (K)(L)(B)(T)(G) are defined in §36. One row per program, with the order parameter it works from, what it proves at theorem grade, and what it explains or leaves open. The third column is the strict one — it records theorem-grade results only, so a program that computes a quantity to high precision without proving it gets no entry there, and the table says as much in the fourth column instead of pretending the distinction away.

Program	**Mechanism / order parameter**	**Proves**	**Explains / leaves open**
Lattice QCD	Wilson-loop area law; Polyakov loop	Area law at strong coupling; lattice existence	Computes (L)(B)(T)(G) to precision; leaves the continuum theorem — and any mechanism — open
Dual superconductor	Monopole condensate; dual Meissner	—	(L) as a picture; $\sim 90\%$ Abelian dominance; which monopoles is open; silent on (K)
Center vortices	Percolating $\mathbb{Z}_3$ flux	—	(L)(T) as a picture; vortex removal kills σ and chiral condensate; continuum formulation open
Gribov / functional	Configuration-space geometry; IR propagators	Bounding statements	Necessary conditions; truncation-limited
Seiberg–Witten	Monopole condensation, derived	**Confinement + gap, as a theorem** — in softly-broken $\mathcal{N} = 2$	The existence proof that rigidity suffices; not QCD
Holography	Worldsheet on an IR wall	Area law for strong-coupling large-N cousins	(L)(T)(G) for cousins; not QCD
This framework	$\mathbb{Z}_3$ holonomy of a real compact cycle; winding as charge; the wall on the scale axis	**(K) outright** (C-P6-1, at the lock's grade); **(L) given the gap** (T-P6-4, §41)	(B)(T) carried consistently; (G) = the named open hypothesis $\widehat{G}$; the pure number σ/Λ^2 owed (§43)

Three observations close the survey. First, *nobody has the theorem*: the only rigorous confinement proof in four dimensions lives in a supersymmetric cousin, and the lattice's analytic result lives at strong coupling. The framework's conditional theorem of §41 enters a field where conditionality is the state of the art, not a special embarrassment. Second, the two mechanism programs with the strongest lattice support — vortices and the dual superconductor — are both *center and topology* stories. The framework's mechanism belongs to that family: it is not an outsider proposing a new kind of answer, but a geometrization of the kind the evidence already favors. Third, Seiberg–Witten's lesson — provability arrives with rigidity — is exactly the wager of the next three sections: this framework's rigid structure is the lock.

39 The center bridge: one $\mathbb{Z}_3$, three jobs

Here is the observation that reorganizes this whole Part — hiding, as the best ones do, in plain sight: *the standard account's own confinement criteria live in the center $\mathbb{Z}_3$ of the color group — the same $\mathbb{Z}_3$ whose holonomy is this paper's lock.*

Walk the standard side first; every clause is textbook (Greensite, 2011). *Who* is confined is decided by triality: the asymptotic string tension survives screening only for sources with $t \neq 0 \bmod 3$ — the fundamental quark, $t = \pm 1$ — while the adjoint, $t = 0$, is screened by gluons and its string breaks. Casimir scaling governs the approach; *N-ality governs the destination. When* confinement holds is decided by the center symmetry: in the pure gauge theory the Polyakov loop — the order parameter valued in the center — averages to zero exactly when the $\mathbb{Z}_3$ symmetry is unbroken, which is the confined phase; deconfinement *is* center-symmetry breaking, its first-order character at 270 MeV inherited from the three-state structure; and with dynamical quarks the center symmetry is explicitly broken — which is precisely why physical QCD has a smooth crossover at 156.5 MeV rather than a transition, and why strings break. And *where* the confining disorder lives, on the best lattice evidence, is in percolating $\mathbb{Z}_3$ vortex flux (§38). Who; when; where: three independent roles, one group of three elements. And the group itself is nothing exotic — it is clock arithmetic with three hours. Every quark advances the clock one hour; every antiquark turns it back one; and only configurations that return the hand to twelve may leave the room as free particles. The whole confinement lore of the standard account is, at bottom, that three-hour clock worn three different ways.

Now the framework's side, all of it proved in Part VI at its stated grade: the lock is the center element $z = W(2) = \mathrm{diag}(\omega, \omega, \omega, 1, 1)$ realized as the holonomy of a real, non-spatial compact cycle; the center identity $e^{2\pi i B} = z$ makes triality literally a winding, $B = t/3$; and the winding is an exactly conserved charge. So:

In the standard account, $\mathbb{Z}_3$ decides who is confined and when — but the center is bookkeeping, a subgroup acting on abstract field space. In this framework the same $\mathbb{Z}_3$ is geometry: a third of a turn of an actual cycle. The quark is confined because a third of a wrap cannot close (C-P6-1); the proton is immortal because a whole wrap cannot unwind (T-P6-2); and the criteria the lattice built its confinement lore on are, in this reading, the boundary shadows of that one twist. One $\mathbb{Z}_3$ — the charge, the cage, and the immortality.

Figure 13 draws the two columns side by side. And one paragraph of the bridge is load-bearing in the *opposite* direction, and the reader deserves it stated with equal force: the two sides do NOT relate the center to the theory in the same way. On the lattice, the center acts as a *symmetry* of the pure-gauge action — a symmetry that can break (deconfinement) and that fundamental matter breaks explicitly (the crossover). In this framework the center element is a *fixed holonomy* — the lock is not a symmetry of an action and cannot break; the winding is a charge, not an order parameter. The bridge is therefore not an identification but a proposal of ancestry: *the reason center-valued order parameters organize confinement phenomenology so well is that the center is, in nature, the holonomy of a real cycle whose windings are conserved charges.* On this reading, center-symmetry breaking at 270 MeV is bulk physics — color mobility in a hot medium — while the readout layer keeps (K) at every temperature, which is exactly the custody split the heavy-ion data enforce (§46); and the explicit breaking by quarks maps to string breaking, the budding of integer-winding endpoints. The disanalogy is not a weakness to hide; it is the content of the proposal.

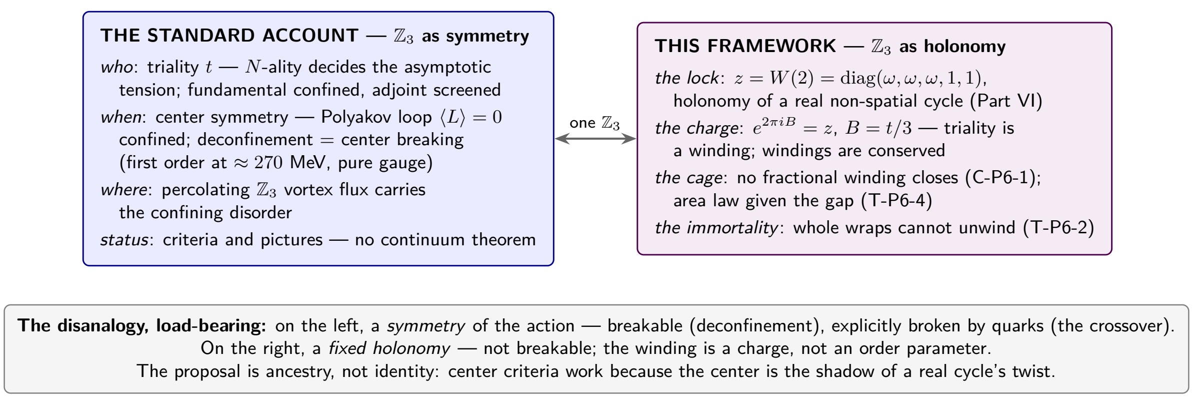


Figure 13: One $\mathbb{Z}_3$, two readings. Left: the standard account's confinement lore — who is confined (triality/N-ality), when (center symmetry and its breaking), where the disorder lives (center vortices) — all valued in the center of the color group, as bookkeeping. Right: this framework's lock — the same center element as the holonomy of a real compact cycle, making triality a conserved winding, with the cage (C-P6-1, T-P6-4) and the immortality (T-P6-2) as corollaries. The bottom box is the honesty clause: symmetry versus holonomy is a real structural difference, and the bridge is a claim of ancestry, not of identity.

40 The wall on the scale axis

The second structural piece is proprietary to this framework's geometry, and it converts a fifty-year-old intuition into geography. In this framework the fifth dimension *is* the renormalization-group axis: $r = \ln(E_{\text{seam}}/\mu)$ (Part II). The color coupling therefore does not merely "run"; it runs *along a direction of the bulk*, and the question "where does the strong interaction become strong?" has a literal answer in coordinates. (A reader wary of extra dimensions may simply read r as the zoom knob of the microscope: every statement below about "descending in r" is a statement about examining nature at coarser resolution, and nothing more mystical than that.)

The answer is priced, with no dial anywhere. The registration $\alpha_s^{-1}(M_Z) = \pi e$ (GG-A9-SM, consumed in Part III) seeds the walk; the boundary theory's own β-function carries it down; the coupling reaches strength at $\mu = \Lambda \approx 340$ MeV; and the corresponding coordinate is

$$r_\Lambda \;=\; \ln\frac{E_{\text{seam}}}{\Lambda} \;=\; 44.3 \;=\; K + 9.3, \tag{33}$$

where $K = 35$ is the lock ($\mu = 3.85$ TeV) and the color flow continues $\ln(M_{\text{lock}}/\Lambda) = 9.3$ e-folds past it. Call r_Λ *the wall.* Two register notes fence the term. First, the wall's *location* is a zero-parameter output of numbers this cohort has already registered; the wall's *existence* — that the color sector's landscape genuinely ends the flow there with a gapped vacuum — is precisely the gap hypothesis $\widehat{G}$ of the next section, and is not claimed. Second, a canon note: the wall lies below the lock, in the infrared continuation of the scale flow; this Part reads it as a feature of the boundary theory's free-energy landscape — the scale at which the singlet basin's curvature takes over — rather than as a geometric endpoint of the bulk interval, whose constitutional extent is fixed upstream. Nothing below depends on the bookkeeping choice.

Now the geometry does work (Figure 14). Hold two fractional-winding sources at boundary separation L and ask where their connecting flux lives in the (x, r) plane. For small L the flux ascends only a short way down the scale axis: the configuration samples the weak-coupling region, and the free energy returns Coulomb-with-running — asymptotic freedom's $-\frac{4}{3}\alpha_s(1/L)\,\hbar c/L$, automatic here because r *is* the RG axis and short distance means shallow descent. For L beyond the crossover, the cheapest configuration changes character: the flux descends to the wall, runs along it, and ascends — and the descent cost saturates (it no longer grows with L) while the wall segment grows linearly. Linearity is then geography:

$$F(L) \;=\; \sigma L + \text{const} + \dots, \qquad \sigma \;=\; c\,\Lambda^2, \tag{34}$$

with σ set by the only scale present at the wall — dimensional transmutation drawn as a picture — and c a pure number this framework now owes (§43). The reader who knows the holographic literature will recognize the drape-on-the-wall mechanism (§38); the reader who knows this cohort will recognize that here the fifth dimension is not a model input but the constitutional scale axis, the wall location is priced by πe, and nothing extended is being postulated: the "string" is the flux tube T-P6-4 derives, not a fundamental object. The Cornell form (30) — Coulomb, crossover, linear — is thereby derived *in form* from the geometry; its coefficients remain quoted from experiment until $\widehat{G}$ and c are paid for.

41 The conditional area-law theorem

The pieces are now on the table: a conserved, quantized winding (the lock); a screening arithmetic valued in thirds (the center); a wall whose location is priced (the scale axis). This section assembles them into the Part's central new result — stated as a theorem with its conditions in the open, because that is what the honesty grammar is for. But first, the point in one plain sentence, for the reader who wants it before the price tags: *if the strong interaction's vacuum has a lowest note — a gap — then the cage follows as geometry, because the flux between fractional charges is a conserved,*

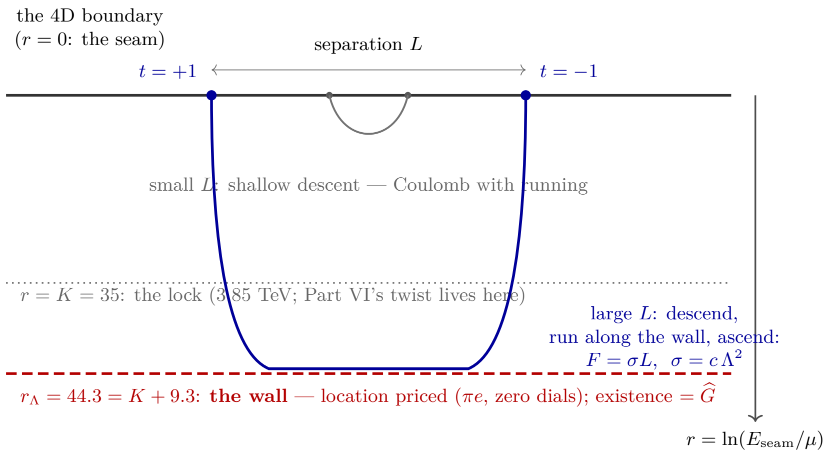


Figure 14: Confinement as geography. The fifth dimension is the RG axis; the color walk, seeded by the registration $\alpha_s^{-1}(M_Z) = \pi e$, reaches strength at the wall (33) — location a zero-parameter output, existence the named hypothesis $\widehat{G}$. Flux between nearby sources stays shallow (Coulomb with running); beyond the crossover the minimal configuration drapes along the wall, whose segment grows linearly with separation — the area law as drawn, with tension $\sigma = c\Lambda^2$ by dimensional transmutation. The lock at $K = 35$ (dotted) is the same axis's marked point from Part VI: one scale direction carries both the twist that writes baryon number and the wall that cages color.

quantized thing that cannot fade, cannot spread, and cannot be neutralized, and such a thing has no option but to bundle into a tube whose cost grows with its length. The theorem's job is to say exactly what that "if" buys; the conditions are the price tags, and they are worth reading, because one of them is the entire remaining debt.

Theorem 41.1 (**T-P6-4**: The conditional area law)**.** *Work on the boundary under the $\mathbb{Z}_3$-locked descent (T-P6-2, at its stated grade), and assume:* ***($\widehat{G}$)*** *the gap hypothesis: the color sector's singlet-stratum free-energy landscape has an isolated vacuum basin, with connected correlations clustering exponentially at a finite length $1/m$, $m > 0$;* ***(A1)*** *locality of GFF (additivity over distant regions up to clustering corrections; constitutional);* ***(A2)*** *exponential clustering under $\widehat{G}$; and* ***(A3)*** *winding superselection — the winding flux through any surface separating sources is conserved and quantized in units of $\frac{1}{3}$ (*not an assumption: the lock, consumed at its grade*). Then for a static source pair of triality $\pm t$, $t \not\equiv 0$ mod 3, at boundary separation L:*

$$F(L) \;\geq\; \sigma_{\min} L - c_1, \qquad \sigma_{\min} \geq c_0\, m^2, \quad c_0 > 0;$$

the minimal-free-energy configuration is a flux tube of transverse radius $\sim 1/m$; no fractional-triality asymptotic state exists at any energy; and the asymptotic tension depends only on t mod 3 — the N-ality law: the adjoint string breaks by screening, the fractional string never does.

Proof structure, in four steps — with the step four dimensions cannot take flagged where it happens.

Step 1: the flux cannot end. The compact cycle has no boundary for winding current to terminate on. Every 3-surface separating the two sources is therefore crossed by winding flux $\equiv t/3$

(mod 1): conserved, quantized, geometric. [Theorem, from the lock.]

Step 2: the Higgs escape is closed — the load-bearing step. In four dimensions, "gap ⇒ confinement" is *false*, and the opening section already named the counterexample: a fundamental-representation condensate screens any source, leaving a gapped, unconfined theory. Every 4D folklore chain from the gap to the area law dies on that rock — there is nothing in a 4D gauge theory to forbid the screening. Here there is, and it is a theorem: by C-P6-1 (§44), every boundary state — hence every condensate, every screening cloud the boundary can form — carries integer winding, $t \equiv 0 \bmod 3$. Screening can shift a source's triality only in steps of 3: a $t = \pm 1$ source can never be neutralized, while a $t = 0$ source can. The confinement criterion *and its one exception* — adjoint screening, hence the N-ality law, hence the broken adjoint string the lattice sees — fall out of the same mod-3 arithmetic. [Theorem, at the lock's grade. This is where the framework converts a fifty-year picture into a derivation.]

Step 3: the gap forbids dilution. Under $\widehat{G}$ and (A2), fields cluster within $1/m$: the flux crossing each separating surface must be carried inside a transverse region of radius $\sim 1/m$, since spreading it wider costs clustering-violation free energy across a larger volume. Quantization (Step 1) forbids carrying less than one quantum of $t/3$; locality (A1) makes the cost per unit of separation additive. Energy per unit length is therefore bounded below: $\sigma_{\min} \geq c_0 m^2$. [Framework derivation; the functional tightening — the precise constant, the surface-decomposition bounds — is a named formal residual, recorded in the registry.]

Step 4: the minimizer is a tube. Additivity plus clustering make the free energy minimal when the flux-carrying region is connected and of minimal cross-section: a tube, $F(L) = \sigma L + \text{end terms} + \text{fluctuation corrections}$ — and the leading fluctuation correction is universal and already measured, which is the next section's story. [Same grade as Step 3.] □

What is new here, and what is not. The *shape* of this argument — quantized, unscreenable flux in a gapped medium must form a tube — is the dual-superconductor and N-ality logic the lattice community has held as a picture for fifty years (§38). What is new and checkable is the standing of the premises: *in this framework the two clauses that keep the picture from being a 4D theorem — flux quantization, and the impossibility of fractional screening — are theorems*, not modeling choices. The framework thereby upgrades "gap ⇒ confinement" from false-in-general (four dimensions) to conditional-theorem (this geometry), at the price of one hypothesis, $\widehat{G}$, whose location on the scale axis is already priced (33) and whose existence this paper does not claim. Seiberg–Witten's lesson (§38) — confinement becomes provable exactly when a rigid structure forces it — is here taken literally: the rigid structure is the lock.

The branch-selection reading, promoted. This paper's ledger has carried the GSSB reading — the color-singlet branch as the unique stable attractor — at grade INT, with promotion registered. T-P6-4 pays that registration: on every $t \not\equiv 0$ stratum the free energy grows without bound along the separation coordinate, so no finite asymptotic minimum exists; the $t \equiv 0$ strata own all the finite basins (the hadrons of Part III). "The singlet branch is the unique stable attractor" is now T-P6-4 plus T-P6-3 in one sentence, at grade D(c) — conditional on $\widehat{G}$ and the lock's own conditions — while the broader GSSB gloss (one selection grammar across the electroweak vacuum, the widths, and the descent) remains what it always was: an organizing interpretation, INT, and priced as such in the ledger.

42 The Goldstone-counting test: the string knows the dimensions are not spatial

One result of this Part is entirely unconditional, and it converts the innocent Lüscher number of §35 into a precision test of this framework's deepest structural commitment. The idea is homely. A stretched string hums, and the character of its hum depends on how many directions it is free to shake in: a string that could vibrate in three transverse directions would carry more quantum jitter than one confined to two. Count the jitter and you have counted the directions — without ever leaving the room. The QCD flux tube is a stretched string a femtometer long; the lattice has heard its hum to a few percent; and this section spends that measurement on the most structural question this framework owns.

The universal term (32) counts massless transverse fluctuation modes of the flux tube: each direction the tube can wobble in contributes $-\pi/24 \cdot \hbar c/r$, and Goldstone's theorem fixes the count — one massless mode per spatial translation the tube breaks. Count them in this framework. The two transverse *spatial* directions are broken by the tube: two Goldstone modes. The *scale* direction contributes none: the tube sits at the wall, which is a minimum of the free energy along r — that is what a wall is — so r-fluctuations are gapped by the basin's curvature. The *phase* direction contributes none: the cycle is compact and holonomy-locked, its excitations starting at the lock scale. Exactly two massless modes; coefficient $-2\pi/24 = -\pi/12$; *exactly what the lattice measures.* Now run the logic backwards, because that is where the test bites. Suppose the fifth and sixth dimensions were *spatial* — ordinary compact space directions, as every Kaluza–Klein and string compactification before this framework would have them — with any radius large enough to matter at the QCD scale. A flux tube in that world breaks the extra translations too: at least one additional massless transverse mode, and the universal coefficient shifts by fifty percent, $-\pi/12 \to -\pi/8$ — at one femtometer, from -51.7 to -77.5 MeV. Lattice string spectroscopy, which confirms the $-\pi/12$ coefficient at the few-percent level, excludes that shift utterly. The measured vibration spectrum of the QCD flux tube is, read this way, a standing experimental statement that *whatever extra structure spacetime carries at the strong-interaction scale, it is not spatial* — and this framework's fifth and sixth dimensions, scale and phase, gapped at the wall and locked on the cycle, pass a test that spatial extra dimensions fail. The constitutional departure this cohort made when it declared the extra dimensions non-spatial — the step Part VII's chronology dates to January 2026 — turns out to have been graded, years in advance, by the vibrations of the QCD string. The Part records this as a passed consistency test, not a falsifier: the framework did not adjust anything to meet it, and there is nothing left to adjust.

43 The number that will judge it: σ/Λ^2

A framework with no dials must eventually put a number where its mechanism is. The wall picture (34) makes the commitment precise: the tension is $\sigma = c\,\Lambda^2$ with c a *pure number*, because Λ itself descends from the registration $\alpha_s^{-1}(M_Z) = \pi e$ with nothing adjustable anywhere in the chain. The measured target is already known to both sides:

$$\frac{\sigma}{\Lambda^2_{\overline{\rm MS}}} \;=\; \left(\frac{440}{340}\right)^2 \;=\; 1.67, \qquad \frac{\sqrt{\sigma}}{\Lambda} \;=\; 1.29, \tag{35}$$

with an honest band of roughly $[1.55, 1.86]$ once the uncertainties of both anchors are carried. The registered commitment, stated as a kill: *when the wall computation of c is carried out (registry item D-P6-4(c)), a result outside* $[1.42, 1.93]$ *— the* $\pm15\%$ *window declared in advance — kills the wall reading of the tension outright, linearity notwithstanding.* A derivation landing inside the band would be, to this paper's knowledge, the first zero-parameter string tension produced by any framework.

What this paper does *not* do is guess the number, and the discipline deserves one sentence of record. The cohort's own look-elsewhere audit (the MSMF/OGN cost procedure of the Standard-Model paper) finds the band (35) dense with cheap closed forms — forty alphabet candidates at low complexity, seven at the lowest — so a registration today would be curve-fitting, and none is made. For the registry only: the ledger's cheapest candidate sits dead center (the ratio $L/N = 5/3$, which would put $\sqrt{\sigma}$ at 438.9 MeV, 0.24% from the lattice value), and it is recorded as *the first value the D-P6-4(c) computation must be tested against* — a candidate awaiting a derivation, carrying no evidential weight until one exists. The number in (35) is the judge, not the verdict.

44 The absent quark: from dynamics to topology

Everything so far — the string, the budding ends, the wall, the conditional theorem — explains why liberating a quark is *dynamically hopeless.* Q5 asks a sharper question: is the free quark merely imprisoned, or is it *not a possible object*? The two readings agree on every scattering experiment ever done and differ absolutely in kind: a prisoner exists behind its wall; a grammatical impossibility does not exist at all. The century could not separate them — it had, as §36 noted, no language in which they differ. Part VI's theorem can, and this section collects the corollary.

Corollary 44.1 (**C-P6-1**: No boundary readout carries fractional winding)**.** *Under the $\mathbb{Z}_3$-locked descent of Theorem* T-P6-2 *(Part VI, at its stated grade), every fragment of the boundary spectrum carries winding $B \in t/3 + \mathbb{Z}$ with its color triality t, and every* asymptotic boundary state *— every configuration the boundary can present as a completed readout — carries integer winding. A lone quark has $t = \pm1$: winding $\pm\frac{1}{3}$ modulo integers, hence no completed readout. The free quark is not a suppressed state of the boundary theory; it is not a state of the boundary theory.*

The proof is one sentence stood on Part VI's machinery: the readout channel is the synchronized cycle, a completed readout closes on that cycle, and a curve cannot close after a third of a turn.

But the picture deserves better than a sentence, because it is the Part's gift to intuition. Baryon number, Part VI will show, is a *winding* — the proton wraps the compact cycle once, in three strands of a third each. Color is the bulk's bookkeeping of the strands; the boundary can only read completed wraps. Asking to detect a free quark is asking to be handed *a third of one wrap of a closed loop* — not a thing that is expensive, or rare, or short-lived, but a phrase with no referent, like the west side of a circle. The sixteen-tonne string of §35 is how the dynamics enforces, at finite energy, what the topology decrees at every energy: pull on a strand and the loop makes you a new loop, because loops are all there is.

Two fences keep the corollary honest. First, the division of explanatory labor, stated once and plainly: *dynamics (QCD, at its own grade) explains why the approach to isolation costs sixteen tonnes of force; topology (T-P6-2, at its grade) explains why the destination does not exist.* The two readings of Q5 that the century could not separate turn out to both be true, at different layers — and the structural one is the answer to the question as asked, because "why has *no* experiment *ever*..." is a question about existence, not cost. Second, what C-P6-1 does *not* say: nothing about the tension's value, nothing about linearity, nothing about the gap. A world in which C-P6-1 held with a logarithmic confining potential would satisfy the corollary; the dynamical content of this Part lives in T-P6-4 and its named hypothesis, not here. Keeping the kinematic jewel and the dynamical debt in separate display cases is exactly what the five-claim scorecard was for.

So the Part can now answer the question it was rebuilt to answer, in one breath: *can this framework explain confinement as a theorem? Today: half — and the better half.* The existence half (K) is a corollary of the lock, at the lock's conditional grade, and it is the half no other program derives. The dynamical half (L) is one named hypothesis from a theorem: given the gap, the area law follows (T-P6-4), the Higgs escape closed by the same lock. The gap itself — $\widehat{G}$, the Clay-hard core — remains open, here as everywhere, its location priced and its existence not claimed. Until it is paid, this Part claims a theorem-given-the-gap and says so in exactly those words.

45 The singlet rule: the triangle's closure condition

C-P6-1 named what does not exist. Its contrapositive is a census of what does — and the census has been in every textbook since 1964 under the name *the color-singlet rule*: the only hadrons nature exhibits are the quark–antiquark pairs and the three-quark bundles, $q\bar{q}$ and qqq, and their conjugates. In the standard account that rule is an output of confinement dynamics, extracted from the same lattice lore as the tension. In this framework it is shorter than that: it is the closure condition of the compact cycle, checkable fragment by fragment in one line of arithmetic per state. This section runs the whole zoo through that one line, says why the answer draws a triangle, and collects an electromagnetic dividend the century has always treated as a separate curiosity.

The one line. Part VI's center identity (§54) gives the action of the center element z on any single fragment: the phase ω^t, with t the fragment's color triality and $\omega = e^{2\pi i/3}$. Phases multiply, and triality adds: on a composite of constituents $t_1, t_2, \ldots$,

$$z:\ |\,\mathrm{state}\,\rangle \longmapsto \omega^T\,|\,\mathrm{state}\,\rangle, \qquad T = \textstyle\sum_i t_i \pmod 3), \tag{36}$$

and the composite's winding on the synchronized cycle is $B = \sum_i t_i/3$, an integer plus $T/3$. Now impose the only requirement the boundary ever imposes: a completed readout closes on the cycle (C-P6-1's premise). A curve closes when its winding is an integer. So:

$$\text{admissible readout} \iff B \in \mathbb{Z} \iff \omega^T = 1 \iff T \equiv 0 \pmod 3 \iff \text{center-invariant.} \quad (37)$$

Four equivalences, each one step of arithmetic. The right-hand end is the group theorist's phrasing of "color singlet under the center"; the left-hand end is the boundary's phrasing of "a state that can actually be handed over." The color-singlet rule is the statement that these ends meet — and here they meet by construction, because they are the same condition read at the two ends of the chain.

The zoo, run through the line. The test is total triality, so it can be administered to any configuration anyone has ever proposed:

Table 9: Every quark configuration, tested for closure. The second column gives the triality modulo three, the third the phase that triality carries, the fourth whether the configuration closes, and the last what the answer means physically. Read down the closure column: only the triality-zero combinations are states of the boundary theory at all. The verdict column is careful to add that the arithmetic selects and the cage enforces, which are two different jobs.

configuration	$T \pmod 3$	ω^T	closes?	verdict
quark q	1	ω	no	not a state of the boundary theory (C-P6-1); the cage of §35 is the dynamics enforcing it at finite energy
antiquark $\bar{q}$	2	ω^2	no	likewise, with the arc run the other way
diquark qq	2	ω^2	no	never free; lives only as a fragment inside a closed loop
meson $q\bar{q}$	0	1	yes	winding 0: closed without wrapping; the lightest completions, and mortal
baryon qqq	0	1	yes	winding 1: one full wrap; carries $B = 1$ forever (T-P6-2)
antibaryon $\bar{q}\bar{q}\bar{q}$	0	1	yes	winding -1: the reflection's image, wrap for wrap (§57)
tetraquark $qq\bar{q}\bar{q}$	0	1	yes	permitted: the rule counts triality, not quarks
pentaquark $qqqq\bar{q}$	0	1	yes	permitted, and nature obliges; rarity is dynamics, not grammar
gluon (adjoint)	0	1	—	passes the triangle's test; its absence from the free list is the gap's work, not the winding's (see the fence below)

The table is the color-singlet rule, with its exact boundary drawn. Everything with $T \equiv 0$ closes; nothing with $T \not\equiv 0$ does; and the rule's true name is the N*-ality rule*, because it counts winding thirds rather than constituents. The exotic rows are worth a sentence: the century sometimes read "only $q\bar{q}$ and qqq" as if quark number were the law. It is not. The law is closure, the tetraquark and pentaquark close, and their observed existence — rare, fragile, but real — is exactly what a closure law predicts and a quark-counting law forbids.

Why a triangle. The geometry deserves to be seen once without algebra. Place the three colors at the three vertices of the equilateral triangle inscribed in the cycle — at 0, $\frac{2\pi}{3}$, $\frac{4\pi}{3}$, the cube roots of unity. A lone quark stands at one vertex: its phase points a third of the way around, and nothing local can point it home. A baryon puts one strand at each vertex: the three phases multiply to $\omega^3 = 1$ — equivalently, the three vertex vectors sum to the triangle's center. A meson pairs a vertex with its conjugate vertex, $\omega \cdot \omega^{-1} = 1$, home again. The triangle is a clock face with three hours; every quark advances the hand one hour, every antiquark turns it back one; and the boundary's door opens only when the hand reads twelve. Confinement, in this picture, is not a wall around the quarks. It is the absence of a door at one-third past.

The electromagnetic shadow. One more column can be added to the fragment table of §54, and it is a column the century has always carried as a separate fact. Run every fragment once more, this time against its electric charge, and one finds — exactly, not modulo anything —

$$Q + \tfrac{t}{3} \in \mathbb{Z} \quad \text{on every fragment;} \qquad \text{equivalently} \qquad e^{2\pi i Q} \;=\; \omega^{-t}, \tag{38}$$

and therefore, by the center identity $B = t/3$,

$$Q + B \in \mathbb{Z} \qquad \text{fragment by fragment.} \tag{39}$$

(Checked, as always, by running the table: u has $Q = +\frac{2}{3}$, $B = +\frac{1}{3}$; d has $-\frac{1}{3}$, $+\frac{1}{3}$; the electron -1, 0; the X at $-\frac{4}{3}$, $+\frac{1}{3}$; every row lands in $\mathbb{Z}$.) Read Eq. (39) through the closure chain (37) and the century's three great never-statements collapse into one: *no experiment has ever seen a free quark; no experiment has ever seen an isolated fractional electric charge; and no boundary readout ever carries an open winding* — one fact, in three laboratory dialects. A fractional charge in isolation would *be* a free triality, which would *be* an unclosed loop presented as closed. That is why F-P6-2 (one confirmed free fractional charge) sits in this paper's falsification table as a kill: it would not merely surprise the model; it would exhibit the grammatically impossible sentence, spoken. The proton's own exact charge — Q2, settled in §25 by the codebook — is the positive print of the same negative: the closure that forbids the fraction alone is what delivers the integer together.

Three fences. First, *triality zero is necessary, not sufficient.* The adjoint gluon passes the center's test, and no free gluon appears in nature's ledger: its exclusion is the mass gap's work — the screening and string-breaking of §39 — which is dynamics (T-P6-4's territory, at its named-hypothesis grade), not topology. The triangle draws the outer wall of the possible; the gap furnishes the interior. Second, and for the same reason, *this section is the kinematic half of confinement only* — claim (K) of the scorecard (§36), the half C-P6-1 delivered. Nothing here prices the string tension, fixes linearity, or touches the Clay problem; the Part's honest division of labor stands exactly as §44 drew it. Third, the rule as derived here rests on the lock, so it is exactly as conditional as

T-P6-2 — and exactly as falsifiable: one free fractional charge (F-P6-2), or one hadron stable in a fractional-triality channel, ends it.

46 The hot crowd: what the quark–gluon plasma does and does not change

A reader current with the heavy-ion program will raise the right objection here, and it deserves a section rather than a footnote. Above the crossover at $T_c = 156.5 \pm 1.5$ MeV (Bazavov et al., 2019), hadronic matter melts into a quark–gluon plasma: color charges screened, mobile, collectively flowing — RHIC and the LHC have produced and characterized this state in exquisite detail. Does a phase in which quarks roam free not falsify §44?

It does the opposite, and the distinction is the custody principle again, now doing experimental work. The plasma is *bulk* color dynamics: a medium, microns short of an asymptotic state, in which color is mobile the way charge is mobile in a metal. The corollary C-P6-1 constrains *boundary readouts* — what survives to a detector as a completed asymptotic state. And the heavy-ion record is unequivocal: every fireball ever produced, at every energy, hadronizes. No fractional charge has ever emerged from a quark–gluon plasma; the crowd disperses only in wraps. Within this framework that is not a dynamical accident to be re-derived per collision energy but the topology holding at the readout layer regardless of how hot the bulk ran: *the plasma unwinds nothing, because the windings were never in the plasma — they are in the reading.* The QGP is thereby promoted from apparent counterexample to the corollary's cleanest stress-test: fifty years of fireballs, zero fractional readouts.

The center bridge of §39 adds the thermal fine print. In the quarkless theory, deconfinement is a genuine first-order transition at ≈ 270 MeV — center-symmetry breaking, its character inherited from the three-state structure of $\mathbb{Z}_3$; in this framework's reading, that is the bulk center order giving way, and its universality class comes along for free. In physical QCD the fractional-winding matter explicitly breaks the center order — which is the same statement as "strings break" (§35), budding integer-winding endpoints — and the transition smooths into the measured crossover. Bulk order melting at one temperature or another; readout topology holding at every temperature: the two-layer custody split is not a rhetorical device but the exact shape of the heavy-ion record.

47 The Clay problem, at this framework's register

The Part's opening contract promised precision about the Millennium Problem; this section pays it, in four moves, because a paper that derives anything about confinement owes its reader exact coordinates relative to the most famous open problem in the subject (Jaffe and Witten, 2000).

Move one: what the problem asks. Construct quantum Yang–Mills theory on $\mathbb{R}^4$ — existence in the constructive-field-theory sense, satisfying axioms at least as strong as the Wightman axioms — for any compact simple gauge group, and prove a mass gap $\Delta > 0$. Existence plus gap. Confinement of fundamental charges is a further, logically distinct property, discussed in the problem's description but not the prize condition; the preamble's care in separating (G) from (K) and (L) is the problem's own.

Move two: what is not in doubt. Nature's answer is not in question — the lattice theory exists rigorously at every finite spacing and its measured gap is 1.71 GeV (Morningstar and Peardon, 1999). The Clay problem is a problem about constructive continuum mathematics, not about whether the world is gapped. No simulation closes it; no experiment could.

Move three: why this framework cannot solve it — structurally, not accidentally. The Clay object is a *closed* four-dimensional quantum field theory on $\mathbb{R}^4$. This framework's constitutional position is that the boundary theory is not closed: it is the GDOS projection of a six-dimensional bulk, its four-dimensional QFT-ness effective rather than axiomatic. A framework whose axioms deny the premise of a mathematics problem does not get credit for the problem — and this paper hereby declines, in advance and in writing, any reading of this Part as a claim on it.

Move four: what this framework can honestly say. It can relocate the physical question. If the D-P6-4 program completes — $\widehat{G}$ established at the wall, the tension's pure number derived — then within this framework nature's confinement and gap are theorems *of an open, projected system*: properties of the free-energy landscape of a boundary that was never a closed 4D field theory. The seventy-year difficulty of proving the same properties inside closed 4D Yang–Mills is then read as a diagnosis: the price of proving a true fact in a frame that omits the structure enforcing it — the compact cycle, the lock, the wall. That is a diagnosis, not a solution; the mathematical problem remains exactly as open, and exactly as important, as before. The framework's relationship to the Clay problem is thus the same as its relationship to the tank: it predicts the silence will hold, explains why from outside the room, and leaves the room's own hard question standing — which is, this paper believes, the only honest posture available to anyone in 2026.

48 The eighty-year null, and the Part's falsifier faces

The experimental record Q5 stands on is one of the great quiet nulls of physics (Navas et al., 2024): Millikan-descended droplet searches, levitometer experiments on bulk matter, accelerator searches at every new energy frontier, sea-water and meteorite and lunar-sample assays — eighty years, no confirmed fractional charge, anywhere, ever. Each null was individually modest; their totality is a wall. The framework's reading converts the wall from an accumulating mystery (*why does the prison never leak?*) into a boundary condition (*there is nothing to leak*).

The faces, sharpened:

F-P6-2, sharpened. A single confirmed free fractional charge — from any source: cosmic ray, accelerator, bulk matter, QGP freeze-out — kills C-P6-1 outright, and with it wounds T-P6-2 upstream (a fractional-winding readout would exhibit an open curve on the synchronized cycle). No parameter absorbs it; this is as binary as falsifiers come. Note what is *not* a kill: millicharged particles from a hidden sector (charge ϵe, no color) would be a discovery about the electromagnetic fiber, not about baryonic winding — the distinction is registered now, before any anomaly arrives to blur it.

The theorem face. T-P6-4 is killed by its own arithmetic in two ways, both stated in advance: a derived tension outside the declared window (§43) kills the wall reading; and any demonstration that a fractional-triality condensate can form on the boundary (contradicting Step 2) kills the theorem's load-bearing step and C-P6-1 with it.

The consistency face. The Goldstone-counting test (§42) is recorded as passed: the lattice's $-\pi/12$ is what non-spatial extra dimensions require, and a confirmed deviation toward $-\pi/8$-like values at long distance would have falsified the framework's dimensional architecture from inside QCD. It did not.

The deconfinement face. Any observation of color screened into an asymptotic fractional readout — e.g. a claimed thermal emission of unconfined quarks surviving hadronization — contradicts the custody split of §46. Five decades of heavy-ion data currently enforce it.

The debt face, as a scoreboard. The registry's D-P6-4 now reads as a scoreboard: (a) branch uniqueness — delivered as T-P6-4's corollary, conditional on $\widehat{G}$; (b) the area law — delivered at theorem-structure grade on $\widehat{G}$ plus the lock, formal tightening named; (c) the pure number — open, the wall computation owed, the target and kill window printed; (d) the Lüscher coefficient — closed, unconditionally; (e) the thermal face — partial, universality inherited, numbers owed with (c). The single deep residual is $\widehat{G}$ itself, and the ledger says so.

49 The Part, in plain English — and its ledger

For the reader who skipped the mathematics — or who wants to check that the mathematics said what it seemed to say — here is Part V again, in plain words.

Nobody has ever seen a free quark, and this Part has told you why twice, at two different depths. The first answer is the century's, and it is about *cost*: quarks are tied together by a cable of gluon field that pulls with sixteen tonnes of force no matter how far you stretch it, and when you stretch it past a femtometer the vacuum finds it cheaper to grow two new quarks at the break than to let the cable lengthen — so pulling on a quark hands you two hadrons, never a bare quark. That answer is measured, magnificent, and still — after fifty years and a million-dollar bounty — unproven from first principles. The second answer is this framework's, and it is about *existence*: baryon number is a winding around a real, closed loop of geometry, each quark carries a third of a wrap, and a third of a wrap of a closed loop is not a rare thing or a costly thing but a phrase with no referent — like the west side of a circle. The century's answer says the door out of the prison is unaffordable. This framework's answer says there is no outside for the door to open onto.

What did this Part actually establish, and what does it still owe? Three things were placed on the table. First, the existence answer just given is a theorem of the lock, at the lock's stated grade — and it is the half of the question no other approach on the market even formulates. Second, the cage itself — the sixteen-tonne linearity — became a theorem *given one missing piece*: if the color vacuum has a lowest note (a gap), then the flux between fractional charges cannot fade, cannot spread, and cannot be neutralized, so it must bundle into a tube whose cost grows with length. That missing piece is the same one the Clay problem turns on; this Part named it, priced its location on the scale axis with no adjustable numbers, and declined to pretend it is proven. Third, a test nobody commissioned came back passed: the quantum hum of the flux tube — a measured correction to its energy — counts how many directions the tube can vibrate in, and the count says *three spatial dimensions and not one more.* A framework whose extra dimensions are places would fail that count; this framework's extra dimensions are scale and phase — not places — and pass. And one number was promised rather than delivered, deliberately: the string tension in units of the theory's own scale, a pure number with no dial behind it, to be computed and not guessed — with the lattice's answer, 1.67, already printed here as the judge that will one day acquit this Part's mechanism or convict it.

For the reader keeping score, the formal ledger follows — every claim of the Part, its grade, and its fences, in the cohort's standard contract form.

Table 10: Status ledger of Part V. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it.

Claim	**Grade**	**Fences / notes**
Clay-grade openness; gap/confinement distinction	D	Stated as the Part's opening contract; existence + gap is the prize condition; nothing below borrows against it.
The measured cage: Cornell, σ, Lüscher, breaking, Casimir, thermal structure (30)–(32)	D	Standard physics (lattice + spectroscopy), cited; arithmetic in Appendix C.
Five-claim decomposition (K)(L)(B)(T)(G)	D	Organisational; each claim graded separately below.
Mechanism survey and Table 8	D	Literature record, cited; no mechanism endorsed beyond its evidence.
The center bridge	INT	One $\mathbb{Z}_3$: ancestry proposal, with the symmetry-vs-holonomy disanalogy stated as load-bearing; standard side textbook, cited.
The wall: location (33)	D	Zero-dial arithmetic from the πe registration; existence NOT claimed (= $\widehat{G}$).
T-P6-4 (conditional area law; N-ality asymptotics)	D(c)	On $\widehat{G}$ + (A1)(A2) + the lock's grade (H3 + R2 + R3); Higgs escape closed by C-P6-1; formal tightening a named residual; Casimir scaling not claimed.
Branch-selection uniqueness	D(c)	Corollary of T-P6-4 + T-P6-3 on $\widehat{G}$; the broader `GSSB` grammar gloss remains INT.
Goldstone-counting test ($-\pi/12$; non-spatial dimensions pass)	D	Unconditional given the tube; lattice-confirmed coefficient; spatial extra dimensions at σ-scale excluded by +50% shift.
$\sigma = c\Lambda^2$ with c pure; target and kill window (35)	CAND	The wall computation owed (D-P6-4(c)); no value registered; candidate L/N recorded without evidential weight.
C-P6-1 (no fractional-winding readout)	D(c)	Corollary of T-P6-2 at Part VI's grade; one-sentence proof; upgrades Q5's "impossible" half from dynamics to topology.
QGP custody split; thermal fine print	INT + D	Reading INT; the zero-fractional-readout record and the pure-gauge/crossover distinction are data, cited.
Clay register (four moves)	D	Declination of credit in writing; the recast labeled a diagnosis, conditional on D-P6-4.
Eighty-year null as boundary condition	D	PDG compilation; reading at C-P6-1's grade.

And now the door this whole Part has been leaning against can open. Twice in these pages a single third-of-a-turn twist of a compact cycle did work that dynamics alone could not: it told the spin it could not decompose (Part IV), and it told the quark it could not leave. Both times the twist was borrowed from a Part that had not yet happened. That Part is next — and it is the one the author has been walking toward for forty-eight years. In Part VI the twist stops being a tool and becomes the story: where it comes from, why it sits at the one point of the hypercharge line the spectrum allows, how it breaks the unified symmetry, evicts the proton's executioners, splits the Higgs, and writes baryon number into geometry — one twist, four locks — and what half a century of silence in a Japanese mine was measuring all along. The quark could not leave the proton. Now we ask why the proton cannot leave the universe.

Part VI
The Immortal Proton

The $\mathbb{Z}_3$-lock writes baryon number; one twist, four locks; Kamiokande (Q6, Q7)

This is the Part the paper is named for, and the third side from which Part III's one fact is read. Grand unification sentenced the proton in 1974. The sentence has never been carried out, and a kilometer of rock and forty years of watching have returned nothing at all. This Part argues that the silence is a prohibition and not a delay. The argument runs through an obstruction and a lock: baryon number cannot be gauged the obvious way, and the Part proves that rather than asserting it; what carries the charge instead is a winding of the compact geometry, written by the center identity. The anomaly ledger is then computed in full, every coefficient of it, so that a reader can check that the single open door is the only opening rather than the only one shown — and that door is what Part X will need.

50 The question, personally

Every Part of this paper so far has opened with physics. This one is entitled to open with a mine. In 1974, unification sentenced the proton to death (Georgi and Glashow, 1974). The sentence was not a speculation bolted onto the theory; it was the theory's crown jewel doing exactly what crown jewels do. SU(5) put quarks and leptons into shared multiplets — the same five-dimensional object holding the down-antiquark beside the electron's doublet — and the gauge bosons connecting the occupants of a shared multiplet turn one into the other. The X and Y bosons were not a bug. They were the unification, embodied. And a boson that turns quarks into leptons turns protons into positrons and pions, at a rate the theory could estimate: slow beyond imagining on a human scale, fast enough to see in a large enough crowd of protons watched patiently enough. The community's conviction had the special firmness of a prediction nobody wanted to be wrong: if the forces unify — and the couplings visibly converged — the proton decays. Through the late 1970s this was, by common consent, the safest bet in fundamental physics.

So we went underground to collect. In a lead-zinc mine in Kamioka, between 1979 and 1985, a small group under Masatoshi Koshiba built a cylinder of three thousand tonnes of water, walled with a thousand twenty-inch photomultiplier eyes, and named it for its purpose: Kamiokande, the Kamioka *Nucleon Decay Experiment*. The author of this paper, then a doctoral student, spent those six years on its design and construction (Arisaka et al., 1985) — the tank, the optics, the electronics that would catch the Cherenkov ring of a positron born from a proton's corpse. We expected, with the field, to see $p \to e^+\pi^0$ within a year or two of switch-on.

The protons declined. Not that year, not that decade, not in the forty years since, not in Kamiokande nor IMB nor Super-Kamiokande's half-century of accumulated megaton-years (Takenaka et al., 2020; Super-Kamiokande, 2024). The experiment, magnificently, refused to waste the silence — solar neutrinos, the supernova burst of February 1987 (Hirata et al., 1987), a Nobel Prize, a new astronomy — but the question it was named for stood unanswered in either direction: the proton would not die, and no theory could say *why not*. The Standard Model's answer — baryon number happens to be conserved by every operator you can write at renormalizable order — is an accountant's shrug, and every deeper theory proposed since 1974 has tended to *break* the accident, not explain it. For fifty years the deepest silence in physics has had no theorem.

This Part supplies the theorem, at its stated grade. The strategy, announced plainly: we take the stability theorem of the Standard-Model paper as received (§51), state the axiom that put $\mathrm{U}(1)_B$ there at all — the founder's own imposition, with its seventy-year lineage (§52) — prove that its one open hypothesis *cannot* be discharged the way the century would first try (§53), find the discharge where the algebra said not to look — in the center of the color group and the topology of the compact cycle (§§54–56) — close the structure with a reflection that turns out to be the CPT companion's central identity (§57), pay the anomaly bill and find exactly one door left open (§58), assemble the completed theorem with its three remaining pins in plain view (§59), and then walk back into the mine to say what the silence meant (§60).

51 The stability theorem, as received

Part II stated the inheritance; here it goes to work. The Standard-Model paper proves (Arisaka, 2026, A9-SM), as its T-SM-60.1, that the proton is absolutely stable *given three hypotheses*: **(H1)** the X, Y bosons live only in the bulk — the boundary spectrum contains the Standard-Model gauge sector and nothing more; **(H2)** the bulk $\mathrm{U}(1)_B$ descends to act on the split boundary fields as baryon number itself — $+\frac{1}{3}$ per quark, 0 per lepton, component by component; and **(H3)** the $\mathrm{U}(1)_B$ gauge anomalies are canceled by the BI-6 Green–Schwarz inflow of GG-A3-BI6. Under H1–H3, every operator with $\Delta B = \pm 1$ or ± 2 carries non-zero $\mathrm{U}(1)_B$ charge and vanishes identically, to all orders; the sole surviving violation is topological, in units of three; the proton cannot decay.

The load-bearing hypothesis is H2, and its home paper said so with unusual candor, deferring the "projection-plus-charge computation" to a successor paper on proton decay. This is that paper, and this is that computation. To see why it deserved a paper rather than a footnote, one must first see why H2 looks *impossible*.

52 The founder's axiom: a QED for baryon number

Before the century's instinct is formalized and defeated, the axiom it will be defeated *about* deserves its own page — because the $\mathrm{U}(1)_B$ in hypothesis H2 did not fall out of a derivation, and this paper refuses to let the reader discover that fact in a footnote. It was put there. The founding move of this framework — in its author's own accounting, the very beginning of the program — was to *impose* $\mathrm{U}(1)_B$ as a local gauge invariance of the bulk, alongside SU(5), in deliberate analogy with electromagnetism. The reasoning is the oldest and most successful in gauge theory: electric charge is not conserved by bookkeeping luck; it is conserved — exactly, locally, at every vertex of every process ever measured — *because it is gauged*. Noether currents of global symmetries can be broken by anomalies, by gravity folklore, by the next layer of physics; the current of a consistent local gauge symmetry cannot. The axiom says: let the baryon obey the same kind of law as the coulomb. Let matter's number be conserved for the same *reason* charge is.

Within the cohort's honesty grammar the statement's rank must be exact: this is an *axiom*, not a theorem. It sits in the constitutional gauge group (3) of Part II, imposed at the same level as SU(5) itself, and nothing in the framework derives it from something deeper. What *is* derived — and is this Part's entire business — is what the imposition costs and what it buys: whether a bulk $\mathrm{U}(1)_B$ can descend to act as baryon number on the split boundary spectrum at all (the obstruction says: not the obvious way), how the geometry pays the debt the obstruction identifies (the center twist), and what the anomaly bill comes to (the ledger, and its one door). The founder imposed the law; the geometry had to be shown able to carry it. That is the precise sense in which H2 deserved a paper rather than a footnote.

The axiom is also not new — and the paper counts that as evidence, not embarrassment. It was proposed, in almost exactly these words, in 1955: Lee and Yang, in a one-page Letter published the year after Yang–Mills, asked whether the conservation of heavy particles might follow from a gauge principle in analogy with electromagnetism — and, in the same page, computed the objection that would keep the idea in exile for most of a century (Lee and Yang, 1955). What happened to their proposal between 1955 and its imposition here — three independent refusals, one wrong revival, a minority line a dozen authors long, and an experimental program that became, without ever quite saying so, a dedicated search for this very force — is a story this paper owes its reader in full, and it is kept where a record belongs, in a Part of its own: Part VII. Here, only the physics of the analogy.

Table 11: The founder's axiom beside its model: $\mathrm{U}(1)_{\mathrm{EM}}$ and $\mathrm{U}(1)_B$, side by side. Both are imposed local gauge invariances; both realize their charge, after descent, as a quantized topological label; both are operator-exact. The two rows in which they differ are the two places the boundary *forced* a bending — and each bending, this Part shows, is load-bearing structure.

	$\mathrm{U}(1)_{\mathrm{EM}}$ **(the model)**	$\mathrm{U}(1)_B$ **(the axiom)**
Origin	Imposed: local gauge invariance	Imposed: local gauge invariance, in deliberate analogy
Anomaly ledger (per family)	All coefficients zero: gaugeable on the boundary as it stands	Two non-zero entries ($[\mathrm{SU}(2)_L]^2 B$, $[\mathrm{U}(1)_Y]^2 B$); payable only by bulk inflow (§58)
The boson	Massless photon; Coulomb's law as the visible signature	Stueckelberg-massive; *no* long-range force — the bending forced by experiment since 1955 (Part VII)
Charge realization	Quantized through the SU(5) embedding (Part III)	Quantized by the center twist: $B = t/3$, the winding of the compact cycle (§54)
Exactness	Exact to all orders	Exact to all orders; sole exception the topological $\Delta B \in 3\mathbb{Z}$ door (§58)
Experimental face	Charge quantization; the neutrality of bulk matter	Proton stability; the equivalence-principle nulls (F-P6-5)

Table 11 states the analogy at its honest resolution. In the bulk it is exact: two Abelian factors of one constitutional gauge group, indistinguishable in kind. On the boundary the analogy had to bend in exactly two places, and both bendings were *forced* — neither is a choice this framework made. First, the anomaly: on the split Standard-Model spectrum the baryonic current is chiral-anomalous, so a four-dimensional gauged $U(1)_B$ is not merely unmotivated but inconsistent — this is the century's strongest reason for declining the axiom, and the framework does not evade it but pays it, through the BI-6 inflow of H3, with the two surviving coefficients becoming the ledger of §58 and the lone $\Delta B \in 3\mathbb{Z}$ door becoming, in Part X, the origin of matter itself. Second, the force: a massless baryonic photon would pull on matter in proportion to its baryon content, and the torsion-balance tradition — from the data Lee and Yang themselves consulted to the modern program — excludes any such force to extraordinary depth; so the boson takes the Stueckelberg mass, the one mechanism that kills the force while leaving the rigid charge and its selection rules exact. Bent twice, broken never: what survives the two bendings is everything the axiom was imposed to secure — a local gauge origin for matter's number, operator-exact conservation to all orders, and a charge that is not a bookkeeping label but a quantized property of the geometry. The sole structural difference from QED that remains is the anomaly line of the table; and that difference, far from being a defect, is the single door through which Part X will bring every baryon in the universe into existence.

In the deep structure, indeed, the analogy ends closer than it began: after descent, *both* charges are windings. Electric charge arrives quantized because hypercharge is locked inside SU(5) and the embedding admits no continuous deformation (Part III); baryon number arrives quantized because the twist is locked to the center of the color group and a winding admits no continuous deformation (§56). The founder's instinct — that the proton's charge-like conservation and the electron's should have the same kind of explanation — is, in the end, discharged more literally than the analogy dared to ask.

The imposition has a personal history, and the paper carries it at testimony grade where it belongs. The instinct did not come to its author from unification; it came through neuroscience — a gauge invariance first written for the information dynamics of the human cortical network, a full year before it was pointed at the baryon — and it took, in his own accounting, fifty years of a physicist's life, Kamiokande included, to trust an imposition the field had declined for seventy. That chronology, dated and marked as testimony, is Part VII's closing section; the sentences that carry it are the author's own.

Now the century's instinct can be formalized — and defeated. The axiom demands that the imposed bulk symmetry act, after descent, as baryon number itself on the split boundary fields. The next section proves this *cannot* be done the way anyone trained in four-dimensional gauge theory would first try; why H2 looks impossible is the right place to begin discharging it.

53 The obstruction: why baryon number cannot be gauged the obvious way

Here is the century's instinct, formalized. If you want an exact $U(1)_B$ acting on the boundary fields, find it a generator: some combination of the Abelian charges available after the descent. What is available? The bulk $U(1)_B$ itself contributes a constant per bulk multiplet — each family is *one* coherent spinor packet (Part II), so one constant per family, or at most one per SU(5) irrep if one imagines relaxing the packet structure. And the descent's surviving Abelian generator is hypercharge Y — the *only* U(1) direction in SU(5) that commutes with the Standard-Model group, because the Standard Model fills SU(5)'s rank. So the most general candidate is

$$B \overset{?}{=} \alpha(\text{multiplet}) + \beta Y. \tag{40}$$

Theorem 53.1 (**T-P6-1**: The rank-matching obstruction)**.** *No assignment of per-multiplet constants* α *and coefficient* β *realizes baryon number on the split Standard-Model spectrum: equation* (40) *has no solution, even granting each* SU(5) *irrep its own constant. Moreover the combination that* is *realizable in this form,* $B-L$*, fails to protect the proton: every dimension-six proton-decay operator conserves it.*

Proof, in full view. Work inside the **10**, which houses three fragments of known baryon number: the quark doublet Q ($B = +\frac{1}{3}$, $Y = \frac{1}{6}$), the up-antiquark u^c ($B = -\frac{1}{3}$, $Y = -\frac{2}{3}$), and the positron field e^c ($B = 0$, $Y = 1$). One constant α_{10} serves all three. The requirement (40) reads:

$$\alpha_{10} + \frac{\beta}{6} = \frac{1}{3}, \qquad \alpha_{10} - \frac{2\beta}{3} = -\frac{1}{3}, \qquad \alpha_{10} + \beta = 0. \tag{41}$$

Subtract the second from the first: $\frac{\beta}{6} + \frac{2\beta}{3} = \frac{2}{3}$, so $\beta = \frac{4}{5}$; then the first gives $\alpha_{10} = \frac{1}{3} - \frac{2}{15} = \frac{1}{5}$. Insert both into the third: $\frac{1}{5} + \frac{4}{5} = 1 \neq 0$. Three conditions, two unknowns, and the system says *one equals zero.* No choice exists; adding a separate $\alpha_{\bar{5}}$ cannot help, since the contradiction lives entirely inside the **10**. □

Two remarks complete the theorem's second sentence. First, the near-miss is itself famous: with (α, β) per irrep one *can* solve for $B - L$ — explicitly, $B - L = \frac{1}{5}(X + 4Y)$ with $X(\mathbf{10}) = +1$, $X(\bar{\mathbf{5}}) = -3$, the textbook charge of SO(10) descent — which is precisely why gauged $B-L$ is commonplace in the unification literature while gauged B is nowhere. Second, that near-miss is worthless for the proton: the four classic dimension-six decay operators ($QQQL$; $u^c u^c d^c e^c$; and their conjugate-pair partners) each carry $B = \pm 1$ and $B - L = 0$ — Appendix D tabulates all four — so an exact $B-L$ lets every one of them stand. The century's road ends here: *if baryon number is to be exact, it cannot be a Lie-algebra charge.* The instinct that gauging B is impossible was correct — at the level of algebras. The theory has more than algebras.

Physics intuition: why the algebra had to fail. Baryon number sees *color* — it pays $\frac{1}{3}$ per quark precisely because quarks come in threes — but it must commute with color rotations, so it cannot live inside the color algebra; and it distinguishes occupants of one SU(5) multiplet, so it cannot live outside them either. It needs to be something an algebra element cannot be: a charge that counts *thirds of color* without touching color's generators. There is exactly one structure in a gauge group with that character — its center — and that is where the discharge is hiding.

54 The center identity: baryon number is color's signature

Inside SU(5) sits the element

$$z \;=\; \mathrm{diag}(\omega,\,\omega,\,\omega,\,1,\,1)\,, \qquad \omega = e^{2\pi i/3}, \tag{42}$$

the generator of the $\mathbb{Z}_3$ center of the color block: a group element, not a generator — a finite rotation with no infinitesimal version, which is exactly how it slips past Theorem 53.1. It commutes with every Standard-Model transformation (it is diagonal, constant on the color block, constant on the weak block), and it acts on any fragment of any representation by the fragment's *color triality* t: phase ω^t, with $t = +1$ for a color triplet, -1 for an antitriplet, 0 for a singlet, additive modulo three under products.

Now the identity on which the whole Part turns. Run through every fragment in the theory — the five matter fragments, the Higgs doublet and its color-triplet partner, the X, Y themselves — and compare ω^t with $e^{2\pi i B}$:

Table 12: The triality of every fragment of the unified multiplet, and the baryon number that follows from it. The first row gives the integer triality, the second divides it by three, and the third is the baryon number. The second and third rows are identical, and that is the table's whole content: baryon number is triality over three, fragment by fragment, with no assignment made by hand anywhere in the row.

fragment	Q	u^c	d^c	L	e^c	H_{doub}	H_{trip}	X, Y
triality t	$+1$	-1	-1	0	0	0	$+1$	$+1$
$t/3$	$+\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0	0	0	$+\frac{1}{3}$	$+\frac{1}{3}$
B	$+\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0	0	0	$+\frac{1}{3}$	$+\frac{1}{3}$

Equality, in every column — not modulo one: *exactly*

$$B \;=\; \frac{t}{3} \qquad \Longleftrightarrow \qquad e^{2\pi i B} \;=\; z \;\text{ on every fragment.} \tag{43}$$

Baryon number was never bookkeeping pasted onto the spectrum. Its fractional content *is the center of the color group*, carried by the SU(5) geometry itself, in plain sight since 1974. What the algebra could not supply — the component resolution — the center supplies for free, because triality is a property of fragments, not of multiplets: Q and e^c share a **10** but not a triality. All that is missing is the promotion of (43) from a phase identity to a genuine, exact, additive U(1) charge — an integer lift of $t/3$. Phases live on circles; lifts of phases are windings. We need the compact cycle.

55 The compact cycle and the abelian ledger: what kind of charge a winding is

The last section ended on a demand: promote the phase identity (43) to an exact, additive charge — lift the phase to a winding, which needs a circle. Before the next section spends the circle, this one is precise about what kind of object lives on it. The answer — *a holonomy* — is worth a section of its own, because it is where three different abelian charges of this framework meet, and where the color group, uninvited, joins them.

Holonomy is gauge invariance, read around a loop. Take any gauge field A and any closed curve C. Parallel transport around C produces the Wilson loop

$$W(C) \;=\; \mathcal{P}\exp\Big(i\oint_C A\Big), \tag{44}$$

and for an abelian field the path-ordering symbol is idle and $W(C) = e^{i\Phi}$ is a pure phase — an element of U(1). Local gauge invariance is the statement that the pointwise phase of a charged field is unphysical: it can be rotated freely at every point, and nothing observable may depend on the rotation. What survives that freedom is exactly the loop integral Φ. A gauge transformation shifts A by a gradient, and a gradient integrates to zero around a closed curve; so the holonomy is the gauge-*invariant* residue of a gauge field — famously a measurable one, since Aharonov and Bohm's solenoid prints precisely this loop phase on an interference pattern that no local field value accounts for. For a reader meeting this for the first time: nothing in the present paragraph is framework-specific. It is what a Wilson loop *is*, in any gauge theory since Wilson. The sentence "the holonomy of S^1_θ" and the sentence "a U(1) gauge phase on S^1_θ" name the same object; one names the geometry, the other the symmetry. What *is* framework-specific is the standing of the circle: S^1_θ is a real, compact, non-spatial cycle of the bulk, so its holonomy is not an analogy for a charge kept elsewhere. It is the charge, kept here. Figure 15 puts the three rungs in one drawing — the loop phase, the Wilson loop, and the difference between a group and a semigroup — because the third is the one this Part leans on hardest.

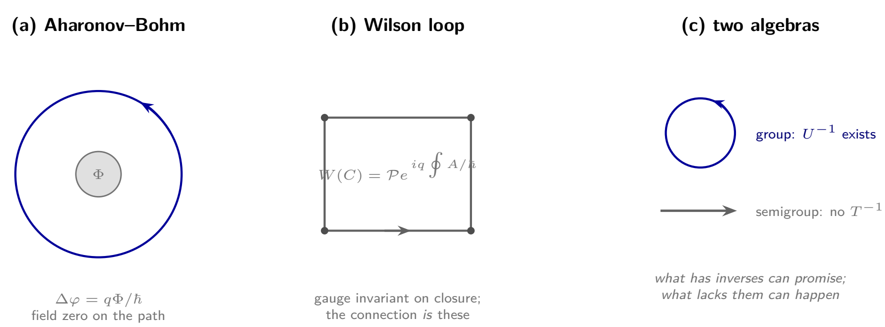


Figure 15: Holonomy, in three rungs, after GG-W2-Holonomy (Arisaka, 2026, W2-Holonomy). (a) The phase is loop data. Aharonov and Bohm's solenoid prints $\Delta\varphi = q\Phi/\hbar$ on an interference pattern although the field vanishes everywhere along the path: the phase is invisible on any open segment and survives every deformation of the closed one. (b) The same statement in gauge language — the Wilson loop (44) is what is left of a connection after the pointwise phase freedom has been used up, and for an abelian field it is a pure element of U(1). (c) The rung this paper needs most, and the one no textbook treatment of (a) and (b) supplies: a group has inverses and a semigroup does not, which is the difference between a symmetry that can be undone and a descent that cannot. All three rungs are standard except the standing of the circle, and the standing of the circle is the whole of §55: S^1_θ is a real, compact, non-spatial cycle of the bulk, so its holonomy is not an analogy for a charge kept elsewhere. It is the charge, kept here.

The abelian ledger of GG-6. The bulk gauge group this paper inherited in Part II (§12) is $\mathrm{SU}(5)\times\mathrm{U}(1)_B\times\mathrm{U}(1)_{Qi}$, alongside gravity. Around the one compact cycle, then, four abelian objects can hold a phase, and it pays to state their four different standings once, in one place:

Table 13: The three circles, and what becomes of each. The middle column says whether the circle is a fundamental factor of the bulk or a direction inside the unified group; the right column gives its fate and the job it does in this paper. The distinction drawn in the middle column is what carries the argument: a rigid charge on a fundamental factor survives exactly, while a direction inside the group is a dial the descent can set.

circle	standing	fate and role
$\mathrm{U}(1)_B$	fundamental bulk factor	anomalous; paid by BI-6 inflow; boson Stueckelberg-massive; the rigid charge survives exactly — *the charge of this paper*
$\mathrm{U}(1)_{Qi}$	fundamental bulk factor	the information circle; one rearrangement, one unit; the proton's register is Part XII's subject
$\mathrm{U}(1)_Y$	not a bulk factor: a direction *inside* SU(5)	the hypercharge Wilson line on S^1_θ is the dial the descent sets; its light fluctuation is the Higgs
$\mathrm{U}(1)_{\mathrm{EM}}$	not a bulk factor: the unbroken diagonal $Q = T_3 + Y$ after the descent	a boundary descendant; conserves charge exactly; carries the triangle's electromagnetic shadow (§45)

Two of the four are constitutional; one is a direction inside the unified group; one is a survivor of the descent. Nothing in the list is new to this paper — but the list itself repays the reader who has wondered, since Part II, how many different things "a U(1)" means here. Four, and they are not interchangeable.

Where an abelian circle touches a non-abelian group. Now the question a careful reader should have been holding since Part V. Confinement is $\mathrm{SU}(3)_C$ physics — non-abelian, three charges, eight gluons. The cycle's holonomy is an abelian phase. By what right does a U(1) worth of phases speak to SU(3) at all?

The answer is a piece of group theory old enough to vote: at the *center*. The center of a group is the set of elements that commute with everything, and for the special unitary groups it is discrete:

$$Z(\mathrm{SU}(N)) \;=\; \mathbb{Z}_N, \qquad Z(\mathrm{SU}(3)_C) \;=\; \{\,\mathbf{1},\,\omega\mathbf{1},\,\omega^2\mathbf{1}\,\}, \quad \omega = e^{2\pi i/3}. \tag{45}$$

A center element is a peculiar hybrid. It is a genuine element of the non-abelian group — yet it is diagonal, it commutes with every transformation, it has no infinitesimal generator, and the Lie algebra is blind to it. That is precisely the profile of the element z of Eq. (42), and precisely how z slipped past the obstruction theorem of §53: the theorem forecloses on *generators*, and the center has none. So the abelian dial and the color group intersect — not everywhere, but at three settings. Turn the hypercharge Wilson line continuously and its holonomy sweeps a circle of phases; at exactly three points of that circle the holonomy is *also* an element of the color center. Those three points —

the cube roots of unity, at 0, $\frac{2\pi}{3}$, $\frac{4\pi}{3}$ — are the vertices of an equilateral triangle inscribed in S^1_θ: *the color triangle*. Everything Part V attributed to the center — who is confined, when, where (§39) — lives at those three points, and everything this Part attributes to the winding does too.

The quotient that was always there. The Standard Model knew this, in its own fine print. The group that acts *faithfully* on the Standard-Model fields is not the textbook product but the quotient

$$G_{\rm SM} \;=\; \big[\,{\rm SU}(3)_C \times {\rm SU}(2)_L \times {\rm U}(1)_Y\,\big]/\,\mathbb{Z}_6, \tag{46}$$

because one specific combination of a color-center rotation, a weak-center sign, and a hypercharge phase — namely $\omega^t\,(-1)^{2T_3}\,e^{2\pi i Y}$ — acts as the identity on every field the Standard Model has. (The check is finite: run the eight kinds of fragment through the phase and watch it collapse to 1 each time. We have run it; it does; the reader can, on the back of the envelope this paper keeps promising.) The $\mathbb{Z}_3$ part of that quotient is exactly the lock of color triality to hypercharge whose additive shadow, $B - 2Y \in \mathbb{Z}$ on every fragment, is the identity the next section spends (47). In the Standard Model the quotient is a true, checkable, and inert remark — a footnote about which group one should have written down, with no dynamical consequence, so almost nobody writes it down. In the present framework the footnote is load-bearing: the $\mathbb{Z}_3$ that color and hypercharge share is realized as the holonomy of a real cycle, and what was a remark about representations becomes the hinge on which Q6 turns.

Physics intuition: the dial and the detents. Put the four abelian standings and the center together and the geometry of the next section can be seen before it is computed. The hypercharge Wilson line is a continuous dial — a full U(1) worth of settings on the compact cycle. Three of those settings are special: at them, the dial's reading is simultaneously a statement in color — a center element of ${\rm SU}(3)_C$. They are detents — the click-stops a machinist cuts into a dial at the settings that matter. The descent must park the dial somewhere (an unparked dial is a massless adjoint scalar the spectrum does not contain), the quantization pin R2 of the next section restricts parking to six discrete settings, and the spectrum's three demands will select the detent $c = 2$ — at which point the dial's reading *is* the color center's generator, and the ${\rm U}(1)_B$ winding and the color triality collapse into one number, $B = t/3$. That collapse is not a metaphor waiting in the wings; it is Eq. (43), already proved fragment by fragment. The next section supplies the only thing still missing: the reason the dial parks at that detent and no other.

55.1 The other fiber: what the interval cannot hold

The ledger above cataloged the abelian objects that live on the compact cycle. Honesty about the geometry requires one paragraph on the bulk's *other* non-spatial direction — the scale interval $r = \ln(E_{\rm seam}/\mu)$ — because its entry in the ledger is empty, and the emptiness is load-bearing. The reason is one exact topological statement: *holonomy requires closed loops, and an interval has none.* No loop on the scale direction ever closes, so that fiber can hold no Wilson phase, no winding, no quantized charge — no gauge-invariant memory of any kind. Transport along it can only compose forward: a semigroup, the dissipative generator of the cohort's open-system law. Where the circle is the bulk's memory — everything on it is quantized, protected, permanent — the interval is the bulk's arrow: it gates, it descends, and it does not return.

For this paper's subject the pair completes an argument that the circle alone cannot finish. The winding theorems of this Part establish that no *operator* can change baryon number; they do not by themselves establish that no *epoch* can. A cosmological history able to revisit the lock — to re-melt the descent, reopen the unified phase, and re-run the twist — would put every winding back into the furnace, and the proton's immortality would be hostage to cosmology. It is not, and the reason is the other fiber: the descent moves along the direction that cannot remember, so the lock crossing is crossed once — promptly, with nothing stored that could fund a return — and the sphaleron door that swings freely above the crossover is welded below it, forever (§58). *The circle protects the winding against every operator; the interval protects it against every epoch.* Stability in this framework is therefore a joint property of the two fibers — a charge the memory cannot drop, carried down a road the arrow cannot re-climb — and the one-way birth of the baryons (Part X) and the permanence of each baryon born are two readings of that single anatomy. The full deployment of the two-fiber observation — symmetry breaking as the one-way reading of holonomy data — is carried by the cohort's symmetry review, GG-W1-Symmetry; this paper records the clause that is the proton's own: *immortal means guarded twice.*

56 The $\mathbb{Z}_3$-lock: one twist, four locks

The descent (Part II) breaks SU(5) by boundary conditions and holonomy on the compact cycle S^1_θ — the Wilson–Hosotani mechanism (Hosotani, 1983), in the orbifold-refined form the unification literature developed (Kawamura, 2001) and GG-A9-SM deploys. The SM-preserving holonomies are exponentials of hypercharge, $W(c) = \exp(2\pi i\, c\, Y)$, quantized (pin R2, below) to integer c with period six. And here the center identity produces its coincidence — except that nothing about it is coincidental:

$$B - 2Y \in \mathbb{Z} \ \text{ on every fragment} \qquad \Longrightarrow \qquad z = e^{4\pi i Y} = W(2). \tag{47}$$

The center element that carries baryon number *is a point on the hypercharge Wilson line* — the very line whose light fluctuation is the Higgs. No new geometric structure is needed; the twist the theory requires is a setting of a dial the theory already owns. Which setting? Scan the six quantized holonomies against the three demands GG-A9-SM's spectrum already makes — break SU(5) (lift X, Y: $y = -\frac{5}{6}$), lift the color triplet ($y = -\frac{1}{3}$), keep the doublet light ($y = +\frac{1}{2}$) — and record, for each, the winding shift $c\,y$ mod 1 it stamps on the matter fragments:

One row passes the spectrum's three demands — $c = 2$, with $c = 4$ its mirror (of which more in a moment) — and in that row, with no further input, the fourth column comes along: *the winding shift equals baryon number on every fragment.* Requiring the Higgs sector GG-A9-SM already has *forces* the holonomy to the center element, and the center element writes B. The pure $\mathbb{Z}_2$ point $c = 3$ — the textbook orbifold parity — is instructive in its failure: it breaks SU(5) but keeps the triplet and lifts the doublet, the doublet–triplet problem *inverted.* The geometry that gets the Higgs right and the geometry that writes baryon number are the same geometry, available at exactly one setting.

Table 14: The Wilson-line shift scanned over its admissible values. Each row asks four yes-or-no questions of one value: whether the unified group breaks, whether the color triplet is lifted, whether the doublet is kept, and whether the shift equals plus or minus the baryon number. Only the row set in bold answers yes to the first four together, which is the sense in which the value is selected rather than chosen.

c	SU(5) broken	triplet lifted	doublet kept	shift $= +B$	shift $= -B$
0	no	no	yes	no	no
1	yes	yes	**no**	no	no
2	**yes**	**yes**	**yes**	**yes**	no
3	yes	no	no	no	no
4	yes	yes	yes	no	yes
5	yes	yes	**no**	no	no

Theorem 56.1 (**T-P6-2**: The $\mathbb{Z}_3$-lock)**.** *With the descent holonomy at the center point $W(2) = z$ (quantization per pin R2; vacuum data per §57):* (i) *each fragment's winding lattice on the synchronized cycle is shifted to $t/3 + \mathbb{Z}$;* (ii) *the chiral zero-mode floors — which survive the twist by index protection, while the unprotected scalar and vector floors at fractional shift are lifted (pin R3 exhibits the profiles) — carry winding exactly B: $+\frac{1}{3}$ for Q, $-\frac{1}{3}$ for u^c, d^c, 0 for L, e^c;* (iii) *the boundary charge of the cycle isometry — the descended* $\mathrm{U}(1)_B$*, gauged in the bulk, Stueckelberg-massive — therefore acts on every boundary field as component-resolved baryon number, discharging H2;* (iv) *the X, Y floors ($t = 1$, shift $\frac{1}{3}$) and the triplet floor are lifted by the same twist, so H1 holds as a corollary rather than a hypothesis; and* (v) *θ-integration enforces winding conservation vertex by vertex: of the component couplings of the two* SU(5) *Yukawa invariants, exactly the three Standard-Model Yukawas survive, every baryon-violating triplet channel is annihilated, and the one surviving triplet coupling is B-conserving.*

The count of what one setting of one existing dial has just done — *one twist, four locks*: it breaks the unified group to the Standard Model; it removes the X, Y from the boundary (H1, the 1974 death sentence commuted); it splits the doublet from the triplet (the classic fine-tuning problem, dissolved — "geometry replaces tuning," as the home paper puts it); and it writes baryon number, component by component, as a winding no operator can unwind (H2). The selection rules of leg (v) deserve one concrete look, because they close a loophole the historically-minded reader will have kept open: in ordinary SU(5), even without X, Y, the color-triplet Higgs mediates decay through its Yukawa couplings. Here the θ-integral prices every component coupling by its total winding: The triplet, already heavy, retains exactly one coupling, and that one is B-neutral: integrate the triplet out and only $\Delta B = 0$ four-fermion operators emerge. The decay channels are not suppressed; they are absent from the theory's vertex list, killed by an integral over a circle.

Physics intuition: the knot. A quark mode wraps the synchronized cycle a third of a turn; a baryon is three thirds — one full wrap. Baryon number is *how many times matter winds the cycle*, and the immortality of the proton is the statement that you cannot continuously unwind a wrapped loop: the proton is stable for the same kind of reason a knot in a closed loop cannot be untied. Part V already spent this intuition on the quark (a third of a wrap is not a state);

Table 15: Every gauge-invariant coupling of the unified theory, with its winding sum and its fate. The couplings whose windings sum to zero survive, and they are exactly the Standard Model's Yukawas together with one more; every coupling carrying a nonzero winding sum is annihilated. The last row is the one to notice, because it survives and it conserves baryon number.

coupling	winding sum	fate
$Q\,u^c\,\tilde{H},\;\; Q\,d^c\,H^\dagger,\;\; L\,e^c\,H^\dagger$	0	survive (the Standard Model's Yukawas)
$Q\,Q\,T$	$+1$	annihilated
$u^c e^c\,T^\dagger$	$-\frac{2}{3}$	annihilated
$u^c d^c\,T$	$-\frac{1}{3}$	annihilated
$Q\,L\,T^\dagger$	0	survives — and conserves B

here it pays its main debt: *a full wrap is a state, and it is a state forever.* What the operators of the boundary theory can do is re-braid the wrap — shuffle flavors, radiate photons, exchange the strands' arrangement — everything the proton's rich phenomenology consists of. What no operator can do is change the number of wraps, because winding is not a quantity the operators carry. It is a sector.

Figure 16 draws the lock itself — the one compact circle, the twist at a third of a turn, and the two kinds of traveler on it.

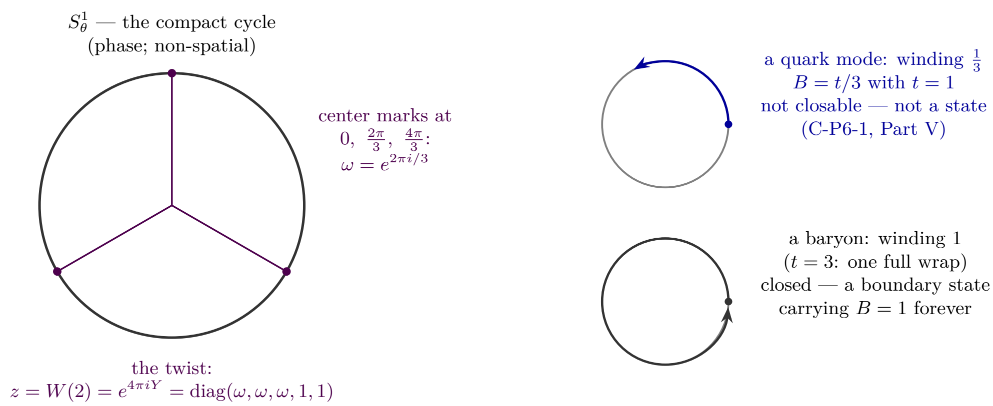


Figure 16: The lock, drawn. *Left:* the compact cycle S^1_θ with the twist at the unique center point of the hypercharge line — $z = W(2) = e^{4\pi i Y} = \mathrm{diag}(\omega,\omega,\omega,1,1)$, the sole quantized holonomy passing the three-demand scan of this section. *Right:* the two kinds of traveler. A quark mode winds by one third — an arc, not a loop: it cannot close, which is why no boundary readout ever carries it alone. A baryon winds once — a closed loop whose winding number is baryon number itself, $B = t/3$ by the center identity (43). A winding can no more be shed than a knot untied in a closed loop. One twist, four locks: the same third-of-a-turn breaks SU(5), lifts the X, Y, splits the Higgs, and writes $e^{2\pi i B} = z$ — baryon number as the winding no operator can change (T-P6-2); that sentence, made precise, is the stability theorem.

57 The dihedral closure: the reflection is P5's

One structural debt remains inside the lock, and settling it produced this paper's deepest point of contact with the cohort. The compact cycle carries not only translations (whose twist we have just set) but the reflection $\theta \to -\theta$ — the parity structure (6) that the descent uses for its chirality projection. A holonomy must be consistent with the reflection: reversing orientation reverses a Wilson line, so consistency demands $R\,W\,R^{-1} = W^{-1}$. Test the naive reading, in which the reflection acts on gauge space by conjugation with P alone: P and $W(c)$ are both diagonal, they commute, and the condition collapses to $W^2 = 1$ — admitting only $c = 0$ (unbroken) and $c = 3$ (the inverted split). *Read strictly this way, the geometry cannot hold the lock at all*: the no-go is as sharp as the obstruction theorem, and it is pointing at the reflection.

The repair is forced, minimal — and already in the cohort's canon. Let the reflection act in the conjugation-twisted form, $R :\ g \mapsto P\,\bar{g}\,P^{-1}$. Then $R\,z\,R^{-1} = P\,\bar{z}\,P^{-1} = z^{-1}$, exactly as orientation reversal demands, and the full structure generated by the shift $S = (\theta \to \theta + \frac{2\pi}{3},\ z)$ and the reflection R closes as the dihedral group $\mathbb{D}_3$: $R^2 = 1$, $S^3 = 1$, $RSR = S^{-1}$ — every relation verified at the matrix level in Appendix D. And a conjugation-twisted θ-reversal is not a structure this paper had to invent: *it is the CPT companion's central identity* — T-P5-A, *conjugation is orientation reversal* (Arisaka, 2026, P5-CPT) — derived there from the real-bulk axioms, consumed here as the closure condition of the geometry that writes baryon number. Two papers, written for different questions, lock: the theorem that gives every particle its twin is the consistency condition for the theorem that makes the proton immortal. Frameworks are supposed to do this and rarely do.

The closure carries one more gift. The reflection maps the lock point to its mirror, $c = 2 \leftrightarrow c = 4$ — which is $B \to -B$: the two admissible orientations of the twist are matter's winding and antimatter's. The dihedral geometry *cannot* carry the baryonic orientation without carrying the antibaryonic one; the antiproton is not an optional extra but the reflection's image of the proton, wrap for wrap — the sister paper's "conjugate readout of the same basin," now visible as the two chiralities of one orbifold. Every precision comparison of proton and antiproton — BASE's sixteen parts per trillion (Borchert et al., 2022) — is a measurement of how exactly the reflection is a symmetry, which is falsifier F-P6-4 earning its keep.

The vacuum-selection question — *why* does the geometry sit at the lock point — is answered by reclassification: the $\mathbb{D}_3$ structure is discrete boundary data, superselected like the parity P itself, not a modulus rolling in a potential; the only continuous holonomy modulus is the Higgs direction, whose minimization is GG-A9-SM's S-6 and is untouched here. And the pin this argument was first carried under — that the deployed descent's reflection genuinely acts on complex representations with the conjugation twist — turns out to be already discharged in the cohort's print: the realization paper states, of the quaternionic structure B of the six-dimensional Weyl module, that it *implements fermionic charge conjugation as real geometry,* $C = (\theta \mapsto -\theta) \circ B$, citing the CPT companion's T-P5-C2 (Arisaka, 2026, A2-GG6). The conjugation-twisted reflection is not an expectation; it is deployed canon, and the dihedral closure stands on it directly.

58 The anomaly ledger, and the one door

An exact gauge symmetry must pay its anomaly bill. Baryon number's, computed exactly (per family; the sums are walked term by term in Appendix D):

Table 16: Every anomaly coefficient of the baryon-number circle, computed rather than quoted. Four vanish outright, one is absorbed by the Green–Schwarz mechanism and is physically inert, and one is nonzero and is the door this Part is about. The table is here because a reader has to be able to check that the door is the only opening: an anomaly account that lists only the coefficient it needs is not an account.

coefficient	value	disposition
$[\mathrm{SU}(3)_C]^2\,\mathrm{U}(1)_B$	0	clean
$[\mathrm{SU}(2)_L]^2\,\mathrm{U}(1)_B$	$+\frac{1}{2}$	**the door** (see below)
$[\mathrm{U}(1)_Y]^2\,\mathrm{U}(1)_B$	$-\frac{1}{2}$	Green–Schwarz-absorbed; physically inert
$[\mathrm{U}(1)_B]^2\,\mathrm{U}(1)_Y$	0	clean
$[\mathrm{U}(1)_B]^3$	0	clean
$\mathrm{U}(1)_B$–grav^2	0	clean

Four of six vanish identically — the assignments are that clean. The two survivors are what hypothesis H3 exists for: the BI-6 inflow of GG-A3-BI6 (Arisaka, 2026, A3-BI6) cancels them in the bulk, the four-dimensional shadow of the mechanism Green and Schwarz taught the field (Green and Schwarz, 1984), and the $\mathrm{U}(1)_B$ gauge boson takes its mass by the Stueckelberg coupling (Stückelberg, 1938) — the venerable trick whose whole point is that the gauge field grows heavy while the *rigid* symmetry survives unbroken. That division is everything: no massless baryonic photon, hence no long-range fifth force (the absence being falsifier F-P6-5's face), yet an exact global selection rule on every operator. The $[\mathrm{U}(1)_Y]^2\,\mathrm{U}(1)_B$ survivor, once absorbed, is physically inert — an Abelian factor has no instantons in four dimensions, so no process ever collects on it.

The $[\mathrm{SU}(2)_L]^2$ survivor is different, and the difference is the whole cosmology of matter. The weak group has topological sectors; 't Hooft's vertex ('t Hooft, 1976) converts the anomaly into real baryon violation — but quantized as $\Delta B = N_{\mathrm{gen}} \cdot n = 3n$, never ± 1, never ± 2, and priced, at zero temperature, at the tunneling factor

$$\Gamma \;\propto\; e^{-4\pi/\alpha_W} \;=\; e^{-372} \;\approx\; 10^{-162}, \tag{48}$$

a number for which words like "suppressed" are theater: the reciprocal exceeds any time scale the universe offers by a hundred and forty orders of magnitude. Cold, the door is welded. Hot — above the electroweak scale, where the barrier can be walked over rather than tunneled through — the same door swings freely, and $\Delta B = 3n$ transitions run unsuppressed. Hold both facts at once and read them forward: *the only baryon-number violation this geometry permits is in units of three, through a door that is open in the early universe and welded today.* A door in units of three cannot leak a single proton ($\Delta B = 1$: not a multiple of three, and no lighter B-carrier exists to share the transaction); it cannot oscillate a neutron into an antineutron ($\Delta B = 2$: likewise); what it *can* do, at sphaleron temperatures, is convert a lepton-sector asymmetry into baryons wholesale — which is precisely the step GG-P5-CPT's birth chain requires and Part X will walk. The equation that forbids one proton's death is the equation that permitted all protons' births. This paper regards that single sentence as Q6 and Q10 shaking hands, and as the strongest internal-consistency statement it owns. Figure 17 assembles the ledger as one flow: six coefficients computed, four zero, two paid by inflow — and one topological door left standing, priced.

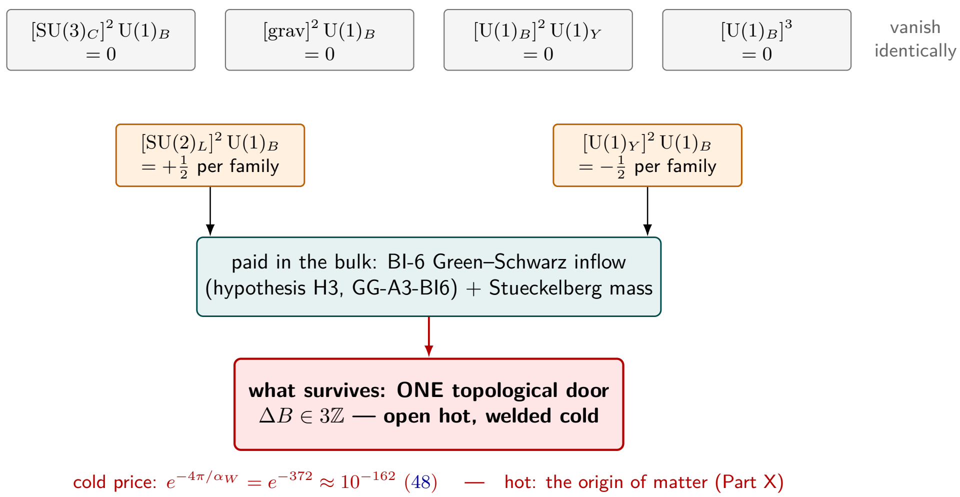


Figure 17: The anomaly ledger of this section as one flow. All six mixed anomaly coefficients of the boundary $\mathrm{U}(1)_B$ are computed exactly (Appendix D): four vanish identically; the two survivors — $[\mathrm{SU}(2)_L]^2 B = +\frac{1}{2}$ and $[\mathrm{U}(1)_Y]^2 B = -\frac{1}{2}$ per family — are absorbed by the BI-6 Green–Schwarz inflow (H3, at its home paper's grade), with the Stueckelberg mass removing the massless mediator. What no inflow can remove is the topological content of the $\mathrm{SU}(2)_L$ survivor: the single $\Delta B \in 3\mathbb{Z}$ door — welded below the electroweak crossover at the 't Hooft price, wide open above it, where Part X will need it.

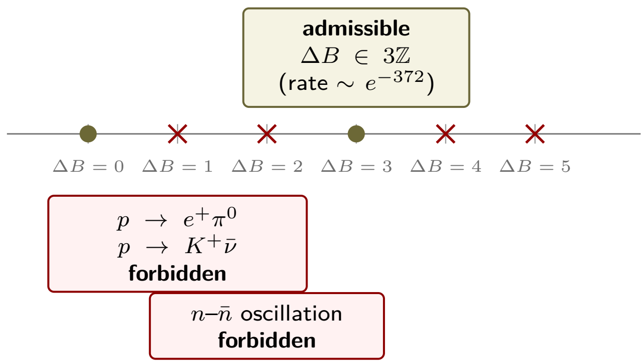
59 The completed theorem

Assemble the movements. The obstruction theorem (§53) closed the algebraic road; the center identity (§54) located baryon number's fractional content in SU(5)'s own center; the $\mathbb{Z}_3$-lock (§56) promoted it to an exact winding charge while delivering H1 and the doublet–triplet split as corollaries; the dihedral closure (§57) certified the structure's consistency on the CPT companion's identity; and the ledger (§58) paid the anomaly bill, leaving the one $3\mathbb{Z}$ door. The stability theorem now reads:

> **T-SM-60.1, completed (statement).** *On the $\mathbb{D}_3$-locked descent, every local boundary operator with $\Delta B \notin 3\mathbb{Z}$ has identically vanishing coefficient to all orders; the sole admissible violation is the topological $\Delta B = 3n$ vertex, of weight (48) at zero temperature. In particular $\Delta B = \pm 1$ (proton decay) and $\Delta B = \pm 2$ (neutron–antineutron oscillation) are forbidden outright: the proton is absolutely stable. Conditional on: H3 (the BI-6 inflow, as received); R2 (holonomy integrality on the Hopkins–Singer clause); R3 (the*

> *warped zero-mode profiles at fractional winding). Each pin is finite, named, and none is a new idea.*

Figure 18 states the theorem as a number line, which is the form in which the two halves of it stop looking like a coincidence: the integers that are forbidden and the integer that is merely expensive are read off the same rule, and the second is the reason there is any matter to ask the question with.



Every canonical proton-decay mode has $\Delta B = 1$; neutron–antineutron oscillation has $\Delta B = 2$; neither integer is a multiple of three, so both are forbidden outright rather than merely suppressed. The thermal reprocessing of Part X lives at $\Delta B \in 3\mathbb{Z}$ and is unaffected. **A single event in either forbidden class falsifies the framework** — and Hyper-Kamiokande will improve the bound on the first class by about an order of magnitude.

Figure 18: The completed theorem as one number line. Baryon number changes only in multiples of the generation count. Every canonical proton-decay mode carries $\Delta B = 1$ and neutron–antineutron oscillation carries $\Delta B = 2$; neither integer is a multiple of three, so neither is suppressed — both are forbidden, with identically vanishing coefficient to all orders. What survives is the topological vertex at $\Delta B = 3n$, admissible and enormously expensive, priced at (48). The two statements are one statement, and the second is why the first is not merely a null result: the same door that is shut to one proton's death was open to all protons' births, and Part X walks through it. The rule is GG-A9-SM's T-SM-60.1 (Arisaka, 2026, A9-SM) as §59 completes it; the rate is this paper's own evaluation, which corrects an imprecise inline figure carried in the earlier literature of the program.

The grade is stated with the care the claim deserves: this is not "the proton is stable, full stop"; it is "the proton's stability has gone from an accountant's accident to a structural theorem with four named, bounded residues," which is — the author would submit — the largest single change in the epistemic status of Q6 since 1974. The sibling symmetry with the electron is worth recording in one line, because the Predictions Branch was built for it: *the electron is immortal because its basin has no exit gate; the proton is immortal because its winding has no unwinding operator.* One framework, two matter pillars, two different kinds of forever.

60 Kamiokande: what the silence meant

Now the Part can walk back into the mine.

In 1980, the logic of the tank was: unification is almost certainly right; unification requires the X, Y; the X, Y kill protons; therefore watch protons. Every clause was reasonable, and the third was wrong in a way nobody could then see — not because the X, Y do not exist, but because of *where* they exist. In the geometry assembled here, the X, Y are real and necessary — they are the off-diagonal blocks of the unified connection, carriers of triality, wound at a third of a turn — and they are *bulk* structure: lifted from the boundary by the very twist that breaks the symmetry, absent not by fiat (H1-as-hypothesis) but as a corollary of the lock. Unification without proton decay is not a retreat or a tuning; it is what unification looks like when the unifying happens in the bulk and the watching happens on the boundary. The 1974 sentence was passed by a theory that put the executioners in the same room as the condemned. The geometry never did.

So the silence was never a null result. Fifty years of it — from the first empty year at Kamiokande through Super-Kamiokande's 0.37 megaton-years (Super-Kamiokande, 2024) — has been a *positive measurement of the winding's exactness*, the longest and most patient confirmation in physics of a selection rule nobody had yet written down. The author spent his twenties building an instrument to watch for a flash that this Part, forty-eight years later, derives cannot come. He is permitted, once, in a paper of record, to say what that feels like; that sentence is his to write, and a placeholder holds its seat.

What the tank means *now* is the part the youngest reader should hear plainly. Hyper-Kamiokande and DUNE and JUNO are not mopping up a dead question; they are aiming at the sharpest kill criterion this framework exposes. The stakes have inverted, and the inversion is the point: *in 1980, a flash in the dark would have crowned unification; in 2030, a flash would kill this framework outright.* F-P6-1 is absolute — one event, any channel, no parameter anywhere to absorb it — and it is matched by its quieter siblings: an oscillation $n \leftrightarrow \bar{n}$ ($\Delta B = 2$; forbidden here as absolutely as decay; the free-neutron bound stands at 0.86×10^8 s (Baldo-Ceolin et al., 1994) with bound-neutron searches reaching an order beyond, and the European Spallation Source proposes the next factor), and a baryonic fifth force (F-P6-5: the Stueckelberg structure permits none). The tank's silence has changed sides — it now testifies *for* a theorem — and the experiments built to break the silence are, exactly thereby, the experiments best placed to break the theorem. A framework can pay an experimental community no higher compliment, and this paper is written in part to pay it: keep watching. Either outcome is now a discovery about geometry.

61 Status ledger of the Part

The summit is climbed; what remains of the paper is the view. The record comes first: where the axiom the summit stands on came from, and why the field declined it for seventy years (Part VII). The neutron will descend through the gate the winding leaves open within a sector (Part VIII); the ladder will climb the excited wraps (Part IX); the birth chain will walk matter in through the one hot door (Part X). And a detector in a mine in Gifu Prefecture will keep watching — which is, this Part has argued, exactly what it should do.

Table 17: Status ledger of Part VI. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it.

Claim	**Grade**	**Fences / notes**
T-P6-1 (obstruction; $B{-}L$ insufficiency)	D	Exact linear algebra, proof in text; operator table in Appendix D.
Center identity $B = t/3$ (43)	D	Fragment-by-fragment, all representations; exact, not mod 1.
$z = W(2)$ on the hypercharge line; uniqueness scan	D	$B - 2Y \in \mathbb{Z}$ all fragments; the c-table; quantization of c = pin R2.
T-P6-2 (the lock; H2 discharged; H1 corollary; selection rules)	D(c)	Conditional on R2, R3; spectrum-level floor survival is GG-A9-SM's deployed claim + R3's exhibit.
Dihedral no-go and C-twisted closure; $B \to -B$ under reflection	D(c)	Matrix-verified relations; the closure condition = T-P5-A + the deployed $C = (\theta \to -\theta) \circ B$ of Arisaka, 2026, A2-GG6 (D-P6-1 discharged).
Anomaly ledger (six coefficients)	D	Exact sums, Appendix D; GS/H3 as received (GG-A3-BI6).
The $3\mathbb{Z}$ door; price (48)	D	Standard topology ('t Hooft), standard evaluation ($\alpha_W^{-1} = 29.6$ at M_Z); open hot, welded cold.
T-SM-60.1 completed	D(c)	On H3 + R2 + R3, each named in place; the grade sentence of §59 is the claim.

Part VII
The Seventy-Year Road to One Letter

A historical record of gauged baryon number, 1955–2026 — the record, not the argument

Physics papers do not usually carry a Part of history, and the reader deserves to know why this one does. The axiom stated in §52 — impose $U(1)_B$ as a local gauge invariance, in analogy with electromagnetism — is the founding act of this framework, and it has a property rare among axioms: it was proposed seventy years before it was imposed, by two of the century's greatest physicists, and then declined by essentially the entire field for reasons that were, in four dimensions, *correct*. That history is not background color. It is the negative image of Part VI's theorem: every objection the seventy years raised against the axiom reappears in this framework as load-bearing structure, and a reader who knows where each wound was inflicted will recognize each member by its scar. The history also carries this paper's oldest personal thread to its origin: the author spent the first six years of his career building the machine that watched for the axiom's failure, and the last two imposing it. Both facts belong in the paper of record — kept in their own Part, precisely so that history and derivation never borrow each other's authority.

62 What this Part is, and is not

The fence first, as always. This Part contains *no physics that the paper's claims depend on*: every theorem, grade, fence, and falsifier concerning $U(1)_B$ lives in Part VI and is untouched by anything said here. A reader who skips this Part loses no equation. What the Part contains is a record, in two registers that are never mixed. The first register is *verified external history*: the published line of gauged baryon number from 1955 to the 2010s, every date and claim cited to the printed literature, checkable by anyone with library access. The second register is *testimony*: the framework's own chronology, 2024–2026, dated by the author and marked as his account — the paper asks the reader to take it as record of *when and in what order* the framework's commitments were made, not as evidence that they are true. Truth is Part VI's business, and the falsification table of Part XII prices it. Nothing in either register is an argument from authority, from priority, or from narrative; the Part's status ledger (§71) closes it the way every Part of this paper closes, with the registers separated in a table.

63 1955: the Letter, and the wound it arrived with

The idea is exactly one year younger than Yang–Mills theory itself. In 1955 — the paper on non-Abelian gauge fields was 1954 — T. D. Lee and C. N. Yang published a Letter of a single page, *Conservation of Heavy Particles and Generalized Gauge Transformations*, asking the question this framework answers (Lee and Yang, 1955): if the number of heavy particles is conserved — and by

1955 the proton's refusal to decay into the lighter particles available to it was already a standing puzzle — should that conservation not have the same *kind* of origin as the conservation of electric charge? Their proposal was the founder's axiom of §52, stated seventy years early: a vector field coupled to baryon number, in analogy with the electromagnetic potential.

And in the same page, with the honesty that marks the whole Letter, they computed the objection. A massless baryonic photon mediates a long-range force between all matter, in proportion to baryon content — repulsive between like baryons — and such a force is composition-dependent: it violates the equivalence principle. The torsion-balance data already in hand, the Eötvös–Pekár–Fekete measurements, bounded the baryonic coupling at roughly one part in 10^5 of gravity (Lee and Yang, 1955) — and gravity is itself some forty orders of magnitude weaker than electromagnetism at nuclear scales. Whatever gauges baryon number, it could not be a second electromagnetism. Lee and Yang proposed the axiom and wounded it in a single page.

The Letter's fate is the era's verdict, delivered bibliographically. It is remembered, cited, respected — and it founded nothing for eighteen years. In its authors' own chronologies it sits as a one-off, flanked by the mainstream concerns of the day. No school formed; no program took the gauging of baryon number as its charge. The idea entered the literature's long memory and stayed there, wounded and waiting.

64 Why the field said no, three times over

The five decades of near-silence that followed were not neglect. They were three independent refusals, each sufficient on its own, each documented, and each — this is the point the record exists to make — *correct within four-dimensional physics.*

First refusal: the conservation came free. In the Standard Model, baryon number is an *accidental* symmetry: the most general renormalizable Lagrangian consistent with the gauge symmetries conserves B without anyone imposing it. To a model builder, gauging B therefore solved a problem the theory did not appear to have — conservation was already there, at tree level, for nothing. That the free conservation was an accident of renormalizable order, unprotected against deeper physics, was well understood; but that understanding pointed the mainstream in the *opposite* direction — toward expecting violation (the third refusal), not toward protecting the accident with a gauge principle. Part I's Q7 is precisely the question this refusal left standing.

Second refusal: the anomaly. The decisive one. On the Standard-Model spectrum the baryonic current is chiral-anomalous: the mixed coefficients $[\mathrm{SU}(2)_L]^2 B$ and $[\mathrm{U}(1)_Y]^2 B$ are non-zero — the exact values, $\pm\frac{1}{2}$ per family, are computed in this paper's Appendix D — and 't Hooft's 1976 analysis made the resulting non-conservation concrete ('t Hooft, 1976), with Kuzmin, Rubakov, and Shaposhnikov showing a decade later that at high temperature the anomaly operates unsuppressed (Kuzmin, Rubakov, and Shaposhnikov, 1985). An anomalous gauge symmetry is not a difficult theory; it is an inconsistent one. Within four dimensions and the known matter content, gauged $\mathrm{U}(1)_B$ is *impossible*, and the standard lore crystallized accordingly: the gaugeable combination is $B-L$ (anomaly-free once right-handed neutrinos are admitted), and the equivalence-principle community itself adopted $B - L$ as the theoretically preferred test charge. Every road around the anomaly required paying in new fermions — "anomalons" — a price the minority line of §67 paid and the mainstream declined. Part VI's obstruction theorem (T-P6-1) is this refusal's algebraic core, proved rather than assumed; and Part VI's answer — pay the bill at six dimensions, through inflow, with the spectrum untouched — is the move no four-dimensional builder had available.

Third refusal: unification wanted the opposite. From 1974 onward the dominant road in fundamental physics was grand unification (Georgi and Glashow, 1974), and its signature prediction — its crown jewel, as Part VI told it — was proton decay. Quarks and leptons in shared multiplets; X and Y bosons connecting them; baryon-number violation not as the problem but as the *point*. A research program whose flagship prediction is the breaking of B does not gauge B; it digs kilometer-deep laboratories to watch B fail — and the author of this paper spent 1979–1985 building one (Arisaka et al., 1985). The refusal here is sociological only in form. In substance it is structural, and it is worth stating with care, because it is the deepest of the three: *in any theory where unification lives on the four-dimensional boundary, baryon-number violation is unification's cost of doing business.* The only escape is to move the unifying off the boundary — and nobody in this lineage proposed that, because there was no bulk on offer to move it to.

Three refusals; one common root. Each is a true statement about four dimensions. The Letter's idea was not wrong; it was homeless.

65 1973: three pages, half the evasion

Eighteen years after the Letter came the first serious step, and its very typography tells the story. A. Pais, 1973, *Remark on baryon conservation* — a "Remark," three pages (Pais, 1973). Pais gauged B as an extra U(1) factor and gave the baryonic boson a mass by the Higgs mechanism, *explicitly to evade the Eötvös constraint*: the first published recognition that a gauged charge does not require a long-range force. This is the direct ancestor of the Stueckelberg logic that Part VI's structure runs on — half the evasion, found. What Pais did not have was the other half: a *reason* for the symmetry (it remained an ornament appended to the electroweak group), an answer to the anomaly (the chiral obstruction is not addressed), and a geometric home (the mass is bought by spontaneous breaking, which puts the exactness of the charge at the mercy of the breaking sector — whereas the Stueckelberg realization of Part VI keeps the rigid symmetry exact while the boson takes its mass). The field's own grading of the idea is preserved in the title and the page count: a curiosity, honestly filed. It gathered no school either.

66 1986–1990: the wrong revival, and the permanent gift

Gauged baryon number reached the front page of the world's newspapers exactly once, and it was wrong. In 1986 Fischbach and collaborators reanalyzed the original Eötvös data and reported a composition-dependent residual, which they interpreted as a finite-range vector force coupled to baryon number (Fischbach et al., 1986) — the "fifth force," its carrier promptly christened the hyperphoton, a direct descendant of the Letter with a mass. For four years it was the most famous idea in physics. By 1990 it was dead: the tower-gravity experiments, the new torsion balances, and the re-examined evidentiary strands all returned null, and the episode closed as one of the cleanest public executions of a hypothesis in modern science.

But the wrong revival left a permanent gift, and for this paper it is the section's point. The fifth-force episode transformed the equivalence-principle program from an occasional precision exercise into a standing, purpose-built search machine — and the charge it optimized its searches for was *baryon number*. The lineage of the experiment Lee and Yang first invoked runs unbroken: Eötvös, Pekár, and Fekete's original balances; the Princeton and Moscow refinements; the Eöt-Wash torsion balances at Seattle; the MICROSCOPE satellite in orbit. The modern benchmark is the Eöt-Wash comparison of beryllium and titanium — test bodies *chosen to maximize the difference in baryon number per unit mass* — with Eötvös parameter $\eta(\mathrm{Be}, \mathrm{Ti}) = (0.3 \pm 1.8) \times 10^{-13}$ (Wagner et al., 2012), and MICROSCOPE has since pushed the frontier near 10^{-14}. Translated into a coupling, a massless baryonic photon is not merely disfavored; it is annihilated — the surviving strength would have to sit dozens of orders of magnitude below electromagnetism's. For this framework the reading is direct and happy: falsifier F-P6-5 — no long-range force coupled to B, ever, at any range with gauge strength — has had a dedicated experimental community since before the theory existed, and the null that community keeps returning, decade after decade, is precisely what a Stueckelberg-massive $\mathrm{U}(1)_B$ demands. The wrong revival built the right instrument.

67 The minority line

There is an honorable minority literature that did gauge baryon number, and the record owes it its due — both because its authors kept the idea alive and because the shape of their solutions measures, by contrast, what the present framework changed. In 1989 Foot, Joshi, and Lew stated the anomaly price in the open (Foot et al., 1989): with the three known generations, gauged B (and L) are anomalous, and consistency demands new fermions with exotic electroweak charges — the anomalons, named and priced, never to leave the four-dimensional ledger. In 1995 Carone and Murayama opened the leptophobic window (Carone and Murayama, 1995): a gauged-B boson lighter than the Z, with coupling as large as $\alpha_B \sim 0.2$, was — astonishingly — still experimentally alive in 1995, a measure of how little the field had cared to look for the force it had spent forty years declining to gauge. And in 2010 Fileviez Pérez and Wise brought the idea into the modern era (Fileviez Pérez and Wise, 2010): baryon and lepton number as local gauge symmetries, anomalies canceled by an extra generation, automatic dark-matter stability advertised as the bonus — fifty-five years after the Letter, gauged B re-entering as beyond-Standard-Model model building, and a small active sub-field following. The line continues into the 2020s, still four-dimensional, still paying the anomalon price, still a bolt-on seeking a home.

Common to every entry in the minority line, from 1973 to the present: four dimensions, so the anomaly must be paid in new matter or new breaking; phenomenology — a Z' to hunt — rather than principle — a conservation law to found — as the motivation; and no connection to unification, which remained not the ally but the *opponent*, since any GUT embedding would break the very symmetry these models gauged. The minority line kept the Letter's question alive for seventy years. What it never had — what nothing in four dimensions could have — was a place where the gauging, the anomaly bill, the missing fifth force, and unification could all be true at once.

68 Ten dimensions, and the brane convergence

One road remains to be recorded, because it is the mainstream road to exactly the consistency problem $\mathrm{U}(1)_B$ poses, and because one of its branches arrived — from the opposite direction — at a structure this paper must acknowledge as kin. The anomaly obstruction that forbids gauged $\mathrm{U}(1)_B$ in four dimensions has a grander sibling: the gauge and gravitational anomalies that threatened all higher-dimensional unification until Green and Schwarz showed, in 1984, that they cancel — in ten-dimensional $N = 1$ supersymmetric theory, and only for the gauge groups SO(32) and $E_8 \times E_8$ (Green and Schwarz, 1984). That single cancellation launched the first superstring revolution, and it fixed the mainstream's price of anomaly freedom for the next four decades: ten dimensions, supersymmetry, and a specific enormous gauge group. In the heterotic and GUT-descended constructions that dominated string phenomenology, baryon number remained what field theory had left it — accidental, approximate, generically violated by the compactification's heavy states. The dominant unification road, at any number of dimensions, never carried an exact B.

The record requires one honest addition, and this paper is glad of it rather than embarrassed by it. In the intersecting-brane Standard-Model constructions of the early 2000s (Ibáñez et al., 2001), every brane stack donates a U(1), and baryon number is *necessarily gauged* at the string level: anomalous in four dimensions, Green–Schwarz-canceled, its boson Stueckelberg-massive, with B surviving as an effective symmetry that protects the proton in perturbation theory — though brane instantons generically violate it beyond. A different lineage, starting from different axioms, arrived at the same *shape* of answer this paper derives: gauged, inflow-paid, Stueckelberg-massive, proton-protecting $\mathrm{U}(1)_B$. The convergence is cited, not hidden, because it corroborates the mechanism while sharpening what is actually distinctive here — the price. What the branes buy with ten dimensions, supersymmetry, and extended objects — and hold only perturbatively — this framework buys with a six-dimensional bulk and the BI-6 inflow, with no supersymmetry and no extended objects, and holds to all orders, the topological $\Delta B \in 3\mathbb{Z}$ door alone excepted. The compact three-clause form of that contrast stands with the others in the Discussion (§94); the record here is only that the convergence exists, and that it was reached from the other shore.

Figure 19 lays the whole road on one axis — the external record above the line, the framework's own dated record below it.

69 The pattern, stated once

Lay the three wounds of the seventy years beside the structure of Part VI and the history inverts. Every fatal objection became a load-bearing member. The record suggests a moral the paper states once and does not lean on: this is the historical signature of a right idea proposed in the wrong dimension. The Letter asked the correct question in 1955; four-dimensional physics returned, three

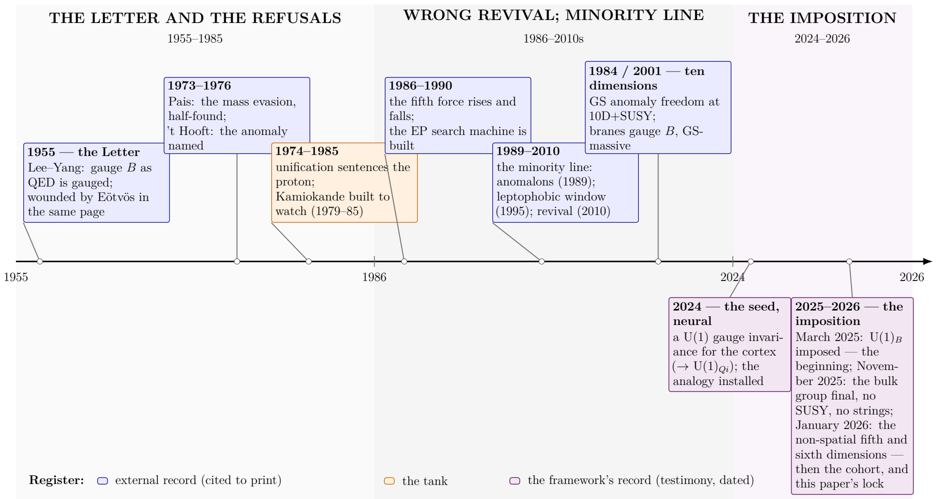


Figure 19: The seventy-year road of gauged baryon number on one axis. Above the line, the external record of this Part, every card cited to print in the text: the Letter and its wound; the mass evasion and the anomaly; the sentence of 1974 and the tank built to enforce it; the wrong revival that built the equivalence-principle machine; the minority line; and the ten-dimensional road with its brane convergence. Below the line, in its own register and color, the framework's dated testimony: the neural seed of 2024, the imposition of March 2025, and the January 2026 departure into non-spatial dimensions. The two registers meet only at the axis — which is this Part's discipline drawn as a picture.

Table 18: The three wounds inflicted on gauged baryon number, 1955–2010s, and what each becomes in this framework. Each row's left entry was fatal in four dimensions; each right entry is load-bearing in six. Three rows, two columns, and the same fact read twice. The left column states each wound as the literature inflicted it; the right column states what that same fact becomes once the arena has six dimensions rather than four. The table is set out in pairs because the claim is not that the wounds were wrong — it is that each of them was a correct measurement of a four-dimensional theory.

The wound (1955–2010s)	**The structure (this framework)**
A massless baryonic photon means a composition-dependent fifth force — excluded from Eötvös–Pekár–Fekete to Eöt-Wash and MICROSCOPE, to depths that annihilate the idea.	The Stueckelberg mass, forced by the same nulls, kills the force while leaving the rigid charge exact; the equivalence-principle program becomes F-P6-5's standing confirmation — a falsifier with its own seventy-year experimental community.
The chiral anomaly makes four-dimensional gauged U(1)$_B$ inconsistent; every evasion costs new fermions the mainstream declined to buy.	The BI-6 inflow pays the bill at six dimensions with the spectrum untouched; the one surviving coefficient becomes the $\Delta B \in 3\mathbb{Z}$ door — in Part X, the origin of every baryon in the universe.
Unification's own X, Y bosons demand proton decay: gauging B and unifying the forces looked mutually exclusive, and the field chose unification.	The $\mathbb{Z}_3$-lock lifts the X, Y to the bulk: unification and immortality stop competing. The 1974 sentence is commuted by geometry, not repealed by retreat.

times over, the correct answer *no*; and the question waited not for a cleverer evasion but for a different spacetime to be asked in.

70 The framework's own record, 2024–2026

The register changes here, and the fence is restated so it cannot be missed: what follows is *testimony* — the framework's internal chronology as its author dates it, recorded so that the paper of record carries its own origin story in its own pages. It is offered as record of when and in what order the commitments were made. No claim of this paper is graded on it.

2024: the seed, and it was neural. The gauge-invariance instinct entered this framework through neuroscience, a full year before it touched the proton. In 2024, working on the information dynamics of the human cortical network, the author formulated a U(1) *dynamical gauge invariance* for cortical processing — explicitly on the analogy of $\mathrm{U}(1)_{\mathrm{EM}}$ in QED: if the brain's processing conserves a quantity the way electrodynamics conserves charge, let the conservation be gauged. That neural U(1) became, in time, $\mathrm{U}(1)_{Qi}$ — the information charge of Part XI — and the analogical move itself became the framework's founding habit. Part XI's candidate is not an appendage to this paper; in the framework's own history, it is the germ.

March 2025: the imposition. The sudden step — in the author's own assessment, *the very beginning of this framework as a physics program*: the realization that the same analogical move, pointed at the baryon, would make the proton absolutely stable. Impose $\mathrm{U}(1)_B$. The moment the neural-side instinct became a claim about the deepest conservation law in matter is the moment the program began; everything in the cohort of papers this one cites descends from it. Fifty years of a physicist's life — the tank included — stood behind the confidence to impose what the field had declined for seventy.

November 2025: the final form. The bulk group settles as $\mathrm{SU}(5) \times \mathrm{U}(1)_B \times \mathrm{U}(1)_{Qi}$ — the two imposed Abelian factors flanking the unification group — the architecture this paper inherits as (3).

Late 2025: the subtraction. Shortly after: the realization that the architecture requires *no supersymmetry and no string-like objects*, and the full formulation of the BI-6 anomaly inflow — the six-dimensional answer to the second wound, and the moment the comparison of §68 became available: what the mainstream road buys at ten dimensions with supersymmetry, the inflow buys at six without.

January 2026: the departure. The final step: the fifth and sixth dimensions defined as *non-spatial* — scale and phase, the radial interval and the compact cycle of Part II — the point of complete separation from every Kaluza–Klein and string compactification before it, and the reason the boundary/bulk custody discipline of this cohort exists at all. From here the public record takes over: the 2026 cohort, the Standard-Model derivation with T-SM-60.1, and this paper, which closes the circle the tank opened.

Table 19: The two columns of the road, 1955–2026. Left: the published external record (verified; citations in the text of this Part). Right: the framework's internal record (testimony, dated by the author). Eighteen rows over seventy years, in two columns that are not the same kind of thing and are not presented as though they were: the left is published and citable, the right is the author's own dated testimony. Keeping them apart is the point of the two-column form — a reader can take the left column on the literature's authority and weigh the right column however they choose.

The external record	**The framework's record**
1955 — Lee and Yang: gauge B as electromagnetism is gauged; wounded by Eötvös in the same page.	
1973 — Pais: the massive-boson evasion, half-found.	
1974 — Georgi and Glashow: unification sentences the proton.	
1976–1985 — the anomaly thread: 't Hooft; the sphaleron era.	
1979–1985 — Kamiokande built to watch B fail.	(the author, underground)
1986–1990 — the fifth force rises and falls; the equivalence-principle machine is built.	
1989 — Foot, Joshi, and Lew: the anomalon price named.	
1995 — Carone and Murayama: the leptophobic window.	
2001 — intersecting branes: B gauged at the string level, Green–Schwarz-massive, at ten dimensions with supersymmetry.	
2010 — Fileviez Pérez and Wise: the modern revival, still an extension.	
2012 onward — Eöt-Wash and MICROSCOPE: the null at 10^{-13}–10^{-14}.	
	2024 — the neural U(1) (dynamical gauge invariance for the cortex; later $U(1)_{Qi}$).
	March 2025 — $U(1)_B$ imposed: the beginning.
	November 2025 — the bulk group in final form.
	Late 2025 — no supersymmetry, no strings; the BI-6 inflow formulated.
	January 2026 — the non-spatial fifth and sixth dimensions.
	2026 — the cohort; T-SM-60.1; this paper, and the $\mathbb{Z}_3$-lock.

Table 19 sets the two columns side by side, and the Part's point sits in their meeting: the left column spends seventy years wounding an idea, and the right column begins by imposing it anyway — not in ignorance of the wounds but because, in a six-dimensional bulk with a non-spatial compact cycle, every wound had become a specification. The Letter asked for a QED of matter's number; the tank measured its silence; the imposition, when it finally came, came from outside the field's own lineage — through a decade of thinking about how brains conserve what they process — and the geometry then did what four dimensions never could. One letter, seventy years, one twist.

71 Status ledger of the Part

Table 20: Status ledger of Part VII. This Part carries no physics claims; its registers are historiographic. Three columns: the content, the register it belongs to, and the anchors or notes behind it. The middle column reads Record or Reading rather than a grade, because a historiographic claim is verified against printed sources and not derived, and using the physics grades here would borrow an authority this Part does not have.

Content	**Register**	**Anchors / notes**
The external history, 1955–2010s (§§63–68)	Record	Every date and claim cited to the printed literature; the Lee–Yang bound quoted from the Letter; final digit-for-digit collation against the primary texts is on this paper's standing pre-release checklist.
The wounds-to-structure reading (§69)	Reading	An interpretive summary of Part VI's results against the record; carries no independent claim — each right-hand entry is graded where it is proved.
The framework chronology, 2024–2026 (§70)	Testimony	Dated by the author; marked in place; no claim of this paper is graded on it.
Physics content of this Part	—	None. The axiom's statement is §52; its discharge, grades, and fences are Part VI's; its falsifiers are F-P6-1 through F-P6-5.

The record is closed, and the paper returns to physics. The proton's immortality is proved at its stated grade; its twin, one wall over, is not immortal at all — and the reason it dies, the direction it dies in, and the fifteen minutes it takes are the next Part's theorem-grade story.

Part VIII
The Shallow Twin

The neutron: 1.293 MeV up-slope, gate-force descent, stabilized by binding (Q8)

After a Part of immortality and a Part of history, a death — the most consequential death in nature, and the gentlest. This Part is about the neutron: why the proton has a twin at all, why the twin sits a hair's breadth up-slope, why it dies in a quarter of an hour on its own and lives forever inside an atom — and why that one arrangement of small numbers is the reason there is chemistry, and readers.

72 The hair's breadth

Having spent a Part on why the proton cannot die, the paper owes equal candor to the particle standing beside it that dies in a quarter of an hour. The neutron is the proton's twin in every respect the strong force can see — same stratum of the ladder, same wrap of the cycle, isospin partners so alike that nuclear physics spent decades treating them as two states of one "nucleon" — and yet, set free, it lasts about fifteen minutes and is gone. Q8 asks three things at once: why the twin exists, why the splitting between the twins is so absurdly small, and why the descent runs in the direction it does, at the leisurely pace it does. All three answers are the landscape again, and this Part is the paper's best worked example of the machinery earning its keep on *numbers*.
Begin with the splitting, because everything hangs on it:

$$m_n - m_p \;=\; 1.293 \text{ MeV} \;=\; 0.14\% \text{ of the nucleon mass.} \tag{49}$$

A seventh of a percent. To feel how narrow that is, run the alternatives. Flip the sign — make the proton the heavier twin — and hydrogen decays: every lone proton in the universe converts to a neutron, there are no atoms, and chemistry never happens. Widen the gap several-fold and the neutron becomes too expensive to stabilize inside nuclei: the periodic table thins toward hydrogen and little else. The observed universe of atoms lives inside a window of roughly an MeV either way, and nature sits in it by a hair (Navas et al., 2024). The century's honest position was that this number was an unexplained mercy. The framework's position is that it is an *output*: the difference of two basin depths, each priced by machinery already on the table, with no dial anywhere in the chain.

73 The competition: two small effects, opposite signs

Why is the splitting small? Because it is a *residual*: two independent, modest effects pulling in opposite directions, and the observed 1.293 MeV is what survives the cancellation.

Effect one: the down-quark's extra toll. Swap a u for a d in the valence content — $uud \to udd$ — and the Higgs toll ledger of §21.5 changes by

$$(m_u + 2m_d) - (2m_u + m_d) \;=\; m_d - m_u \;=\; 2.51 \text{ MeV} \tag{50}$$

in favor of a heavier neutron. In the framework's terms: the d-basin's Yukawa toll exceeds the u's (the codebook of GG-A9-SM, at its grade), so the twin one rung over in isospin pays more rent.

Effect two: the proton's electromagnetic bill. The proton is charged; its Coulomb and magnetic self-energy raises its basin relative to the neutral twin's by roughly an MeV in the opposite direction. For most of a century this competition could only be estimated; the modern lattice, with quantum electrodynamics included alongside chromodynamics, computes both terms from first principles (Borsanyi et al., 2015): the quark-mass contribution $+2.52 \pm 0.29$ MeV, the electromagnetic contribution -1.00 ± 0.16 MeV, total consistent with (49). Note the first number against (50): the full nonperturbative quark-mass effect lands within a hundredth of an MeV of the naive current-mass difference — the storm, for once, politely canceling out of a difference of twins.
So the hair's breadth is not a mercy; it is an arithmetic:

$$m_n - m_p \;=\; \underbrace{(m_d - m_u)\text{-toll}}_{\approx +2.5 \text{ MeV}} + \underbrace{\text{EM self-energy}}_{\approx -1.0 \text{ MeV}} \;\approx\; +1.3 \text{ MeV}, \tag{51}$$

and each term traces to framework inputs — the Yukawa codebook and the fine-structure constant, both GG-A9-SM's registrations at GG-A9-SM's grade. The window that permits chemistry is the gap between two of the codebook's smallest entries. The reader is invited to sit with that for a moment; the Part will still be here.

74 The descent: why fifteen minutes

A free neutron is a Geometric Attractor (GA) that is not the ground: it sits 1.293 MeV up-slope from the proton's ground attractor with its strong and electromagnetic channels closed — same stratum labels apart from charge, and no strong process changes a d into a u. Exactly one channel remains: the gate force. In the basin/gate architecture inherited from GG-A9-SM, the weak interaction is the unique channel through which descents between basins run — it is how the muon found the electron in the sister paper, and it is how the neutron finds the proton here:

$$n \;\longrightarrow\; p + e^- + \bar{\nu}_e, \qquad Q \;=\; (m_n - m_p) - m_e \;=\; 1.293 - 0.511 \;=\; 0.782 \text{ MeV}. \tag{52}$$

The GRIP-In reading prices this descent, and the price explains the quarter hour. Two suppressions stack. The gate is *weak*: the amplitude carries Fermi's constant, and the rate its square — already ten orders below a strong descent. And the doorway is *narrow*: the released energy 0.782 MeV must be shared among three bodies, and the phase space available scales, by Sargent's rule, as the fifth power of the energy release, $\Gamma \propto Q^5$. The neutron's Q barely clears the electron's mass; the fifth power of a small number is a tiny number. For calibration: the muon, descending through the same gate with $Q \approx 105$ MeV, decays in 2.2 μs — and the ratio of the two phase-space factors alone, $(105.7/0.782)^5$, is ten orders of magnitude (Appendix E). Same gate, same grammar; the pace difference is almost entirely the doorway's width.

Better than calibration, the number itself is computable at the blackboard, and Appendix E walks every step: Fermi's constant, the axial coupling $g_A = 1.2756$, the quark-mixing element $|V_{ud}|$, and the exact three-body phase-space integral assemble into

$$\tau_{\text{tree}} = 914 \text{ s}, \qquad \tau_{\text{corrected}} \approx 878 \text{ s} \quad \text{(radiative/recoil, few percent)}, \tag{53}$$

squarely on the measured bottle value of 877.75 ± 0.28 s (Gonzalez et al., 2021). A student who has followed this paper from the transmutation walk of Part III now holds both ends of a remarkable chain: the same framework registrations that priced the proton's *mass* also price the neutron's *patience*, and both land on experiment with no dial between.

Figure 20 draws the two situations of the twin side by side: free, with its one narrow gate open; bound, with the landscape re-shaped and the gate sealed.

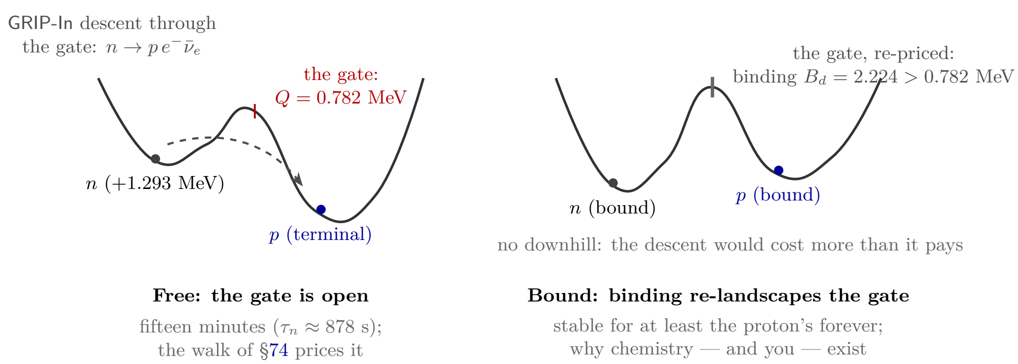


Figure 20: The shallow twin's two situations. *Left, free:* the neutron sits 1.293 MeV up-slope of the proton's ground attractor with exactly one narrow gate — the β endpoint $Q = 0.782$ MeV — and the GRIP-In descent through it takes about fifteen minutes, priced by the standard electroweak walk this Part quotes. *Right, bound:* inside a nucleus the landscape is environmental — the deuteron's binding of 2.224 MeV exceeds the free gate's 0.782 MeV, the descent would cost more than it pays, and the gate is sealed: the bound neutron is as immortal as the proton. One number on each side of one inequality is why nuclei, chemistry, and readers exist.

75 The landscape is environmental: why chemistry exists

Here is the Part's most consequential sentence, and it looks almost too simple to matter: *binding energy moves basins.* A neutron inside a nucleus is not the free neutron plus decoration; it is a configuration of a different landscape, in which the binding contributes to the depths. In the deuteron, the gentlest laboratory case, the binding energy is 2.224 MeV — and the would-be descent must pay it to break the bond, while the doorway only supplies $Q = 0.782$ MeV. The account does not balance; the channel is *energetically closed*; the bound neutron shares the terminus's immortality

(Appendix E does the general bookkeeping). Every stable nucleus beyond hydrogen is a neutron sanctuary built by the strong force out of exactly this arithmetic — which is to say: *chemistry exists because binding re-landscapes the gate.* And the door swings both ways: in proton-rich nuclei the local landscape tilts the other way, and it is the *proton* that descends (β^+ decay, electron capture) — not a violation of Part III's terminality but its refinement: the GGA of *the isolated stratum* is the proton; embed the stratum in a nuclear environment and the functional, hence the floor, is the environment's. The landscape was never a fixed backdrop. It is the physics.

For the reader in the tank. This section is your fiducial volume. Super-Kamiokande's oxygen and DUNE's argon are sanctuaries in the above sense: their neutrons are as immortal as their protons, which is why your background model does not include 10^{33} neutrons decaying in your detector at fifteen-minute half-lives — a background that would otherwise end the proton-decay program before breakfast. The same landscape shift that lets you exist as chemistry lets your experiment listen for a single decay in silence.

76 The two clocks: reporting a discrepancy without adopting it

Precision has produced a puzzle, and this paper's honesty register requires it be reported exactly as it stands. Two mature techniques time the neutron. Bottle experiments trap ultracold neutrons and count survivors: $\tau = 877.75 \pm 0.28$ s (Gonzalez et al., 2021). Beam experiments watch a cold beam and count the protons born in flight: $\tau = 887.7 \pm 2.2$ s (Yue et al., 2013). The methods disagree by about ten seconds — roughly four standard deviations — and have for a decade. The mundane resolution is an unaccounted systematic in one lineage; the exotic resolutions propose an invisible decay channel that bottles count and beams miss.

This paper claims nothing about the resolution, and says so. But the framework does contribute one *constraint*, and it is sharp: whatever the resolution, *the winding survives it.* Any exotic channel must carry the neutron's $B = 1$ intact into its final state — a dark-sector destination would have to be a baryonic-winding carrier, a wrapped state of a hidden stratum — because $\Delta B = 1$ disappearance is forbidden here at exactly the grade of Part VI's theorem, not by model preference. A confirmed neutron disappearance channel with *nothing* carrying the wrap away would falsify T-P6-2 as surely as a proton decay (it is F-P6-1's sibling); a channel with a wrapped invisible daughter would be a discovery *about the landscape's hidden strata* and entirely survivable. The discrepancy is thus a watch item with a built-in diagnostic: the framework tells the experimenters exactly which version of the exotic would kill it.

77 Status ledger of the Part

The twin's story ends where the proton's began: one basin, one gate, one hair's-breadth number that had to fall where it fell for anyone to be here doing the measuring. The next Part climbs away from the nucleon floor entirely, up the tower of copies that all crumble — and asks why the crumbling itself is so beautifully graded.

Table 21: Status ledger of Part VIII. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it.

Claim	**Grade**	**Fences / notes**
Splitting decomposition (51)	D	Lattice QCD+QED, cited; framework content = the inputs' provenance (GG-A9-SM, at grade).
Gate-descent reading of β-decay; direction	D(c)	On the basin/gate architecture (GG-A9-SM) and GRIP-In (GG-A6-GRIP); direction fixed by (51).
Lifetime walk (53)	D	Standard electroweak computation, every step in Appendix E; corrections quoted, not derived.
Bound stability; environmental landscape	D	Energy bookkeeping, general and per-nucleus; the "chemistry exists" corollary.
Bottle–beam discrepancy	—	Reported, not claimed; the winding constraint on exotic channels stated at T-P6-2's grade.

Part IX
The Ladder

Six flavors from $N = 3$; the excited tower; the width-zero terminus (Q9)

The proton is the ground floor of a tall building. This Part climbs the rest of it: six quark flavors where fewer might have seemed enough, and above the proton a whole tower of excited copies, every one of which crumbles almost the instant it forms — while the bottom rung lives forever. The question here is not why the tower crumbles, but why the crumbling is so beautifully graded, and why exactly one rung is exempt.

78 Six, and why six

The proton's quarks come in flavors, the flavors come in families, and the families come in exactly three — a count the Standard Model carries as an input and this program derives as a theorem. The derivation belongs to the sister paper and is consumed here in one paragraph, at its declared grade (Arisaka, 2026, P2-N3): three or more families are *required*, because with fewer than three there is no physical CP phase and the constitutional demand for maximal structure at minimal freedom (the MSMF axiom of GG-A1-Constitution) is violated; three or fewer are *permitted*, because the capacity theorem of the sister paper prices the ladder in this paper's favorite currency: the stratum's income is π of instanton budget per family (its topological charge, converted at the smallest coin the landscape mints), while the descent's tolls total the triangle number $\pi N(N-1)/2$ — linear income against quadratic expenses, so the books balance only through three families, and at three they balance *exactly*, 3π against 3π, with nothing left to fund a fourth family's road to the ground state. Squeezed from both sides, $N = 3$ — the two-sided pincer, carried at "derived (conditional)" with its fences (the coupling clause and the integrality lemma L-INT) stated at home. Each family contributes one up-type and one down-type flavor to the quark sector, so the flavor count follows by doubling:

$$(u, d), \qquad (c, s), \qquad (t, b) \implies \text{exactly six,} \tag{54}$$

and Q9's first clause — *why six?* — reduces without residue to *why three?*, which is answered elsewhere and owned there. What this Part adds is perspective on the ladder the six span: the up quark's toll is 2.16 MeV and the top's is 172,570 MeV — a factor of 8×10^4 between rungs of the *same* ladder, the cascade-toll hierarchy of GG-A9-SM's codebook. The proton is built from the two cheapest rungs. Everything in this paper so far — the ground attractor, the hair's-breadth twin — lives in the ledger's bargain basement, and that is not an accident: the floor of a landscape is found where the tolls are lowest.

79 The tower above the floor

Fix the winding at $B = 1$ and climb. Above the nucleon floor rises a tower of excited readouts — the baryon spectrum, one of experimental physics's great catalogs, four hundred-odd entries deep (Navas et al., 2024) — and this Part's claim is that the entire catalog is organized by one variable the century rarely named: *what protects each rung, and how well.*
Three specimens carry the whole lesson.

The $\Delta(1232)$: nothing protects it. The first rung: same quarks as the nucleon, spins aligned instead of paired — 294 MeV up-slope with a strong channel gaping open ($\Delta \to N\pi$). Width 117 MeV; lifetime 5.5×10^{-24} s; the readout barely completes before the descent reclaims it. This is the landscape's default: an excited wrap with a strong channel open is a suggestion, not a particle.

The Ω^-: strangeness protects it, thirteen orders' worth. The crown of the 1964 decuplet — three strange quarks, spin $\frac{3}{2}$, predicted with its mass by the Eightfold Way and found on cue in a bubble chamber (Barnes et al., 1964), the discovery that made quarks impossible to disbelieve. Every strong descent from the Ω^- is closed — not by energy but by *labels*: no lighter $B = 1$ state can absorb its three units of strangeness, and the strong force cannot change flavor. Its only road down is the gate, one strangeness unit per transit, and the gate's price shows: lifetime 0.8×10^{-10} s — *thirteen orders of magnitude* longer than the Δ's, for a particle only half again as heavy. Same tower, same storm; the difference is purely which channels the labels close.

The proton: everything protects it. The terminus. Strong channels: closed (no lower floor — Part III). Gate channels: closed (no lower $B = 1$ relative at any charge). Winding channels: closed to all orders (Part VI). Width: zero. The tower's grading, assembled: Twenty-six orders of

Table 22: The ladder read from the top down, rung by rung. Each row gives the lowest channel still open to that state, the lifetime that follows, and what protects it. The lifetimes climb through more than twenty-five orders of magnitude and then stop: the last row has no open channel at all, and what protects the proton is not a quantum number imposed on the spectrum but the winding itself.

rung	open channel	lifetime	protected by
$\Delta(1232)$	strong	5.5×10^{-24} s	nothing
$\Lambda(1116)$	gate (one unit)	2.6×10^{-10} s	strangeness
$\Omega^-(1672)$	gate (thrice over)	0.8×10^{-10} s	strangeness $\times 3$
n (free)	gate (hair's-breadth Q)	879 s	phase space
n (bound)	none	stable	binding (Part VIII)
p	none	∞	the winding itself

magnitude between the tower's top row and its fifteen-minute row, another eternity to the last — and one grammar throughout: *a lifetime is the price of the cheapest open descent, and the labels decide what is open.* Part III displayed this column as evidence that the landscape is real; this Part has now walked every mechanism in it. The baryon tables, read this way, stop being a catalog and become a contour map.

Figure 21 plots the grammar of the ladder as one staircase: every rung's lifetime is the price of its cheapest open descent, and the floor — with no descent at all — falls off the bottom of any finite chart.

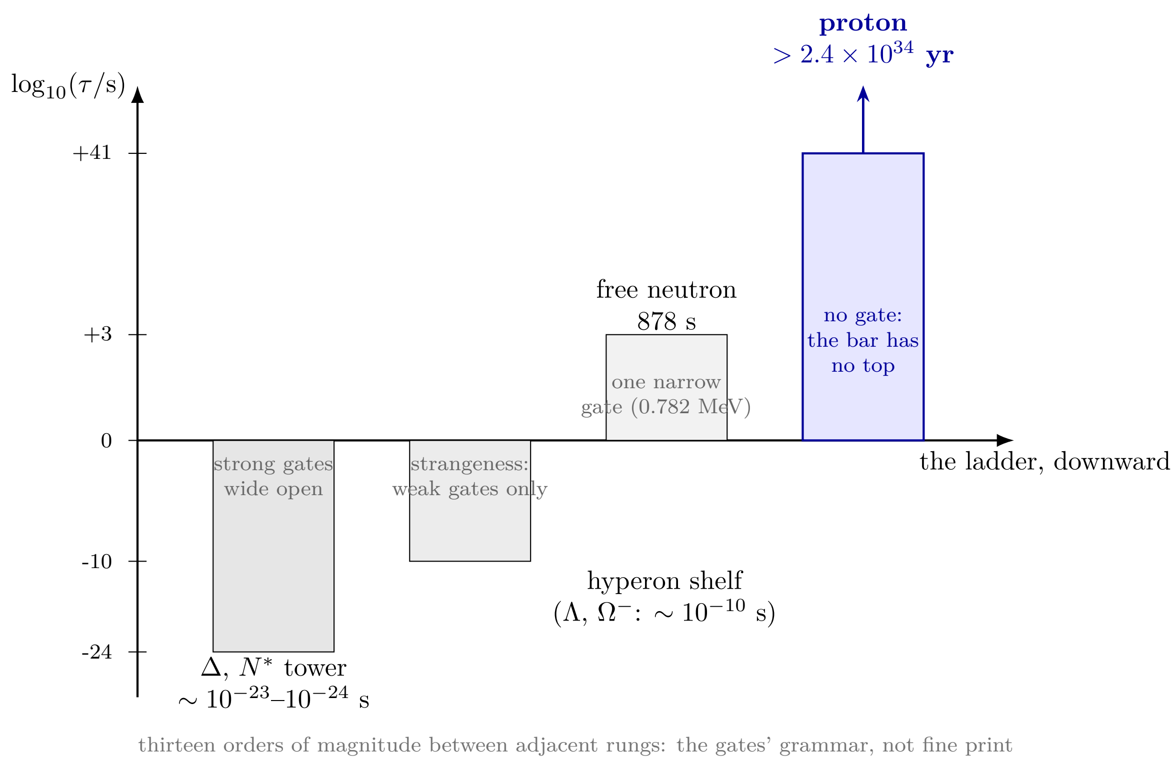


Figure 21: The ladder's grammar as one staircase: $\log_{10}$ of each rung's lifetime. The excited tower decays through wide-open strong gates in $\sim 10^{-23}$ s; strangeness closes the strong gates and the hyperon shelf lives $\sim 10^{-10}$ s — thirteen orders of magnitude for one label change; the free neutron has exactly one narrow weak gate and lives fifteen minutes; and the proton's bar has no top, because a basin with no gate has no lifetime scale at all — the observed bound $> 2.4 \times 10^{34}$ yr (Takenaka et al., 2020) is a floor on an infinite bar, not an approach to a ceiling. Lifetime is not a property sprinkled on particles; it is the price list of the open gates, and the ladder reads it off label by label.

80 Copies, not cousins

One conceptual point keeps the ladder honest, inherited from the sister paper's treatment of the muon and worth its own section here. The excited baryons are not new basins — they are *higher floors of the same stratum*: excited readouts of the one wrapped configuration, reached by spending energy on spin alignment, orbital excitation, or costlier rungs of the flavor ladder. Two consequences follow, both measured facts. First, *identity holds on every floor*: all Δ^{++}s are identical, all Ω^-s are identical — the floors are floors of a functional, not populations with histories, and the identity corollary of Part III applies rung by rung. Second, *every floor above the terminus has a width* — being a floor and not the floor means a descent exists, and GRIP-In prices it. The converse is the sharp statement: in eighty years of spectroscopy, no excited baryon has ever been found with zero width, and the framework says none ever will be — a second zero-width $B = 1$ state is already registered as a kill in §27, and the tower is where such a thing would have surfaced. The ladder's every rung crumbles, on schedule, at the price its labels set; the universe is built from the one rung that cannot.

For the reader in the tank. The tower is your signal model. When an atmospheric neutrino strikes your fiducial oxygen, the Δ it excites decays before it travels a fermi, and the pion it sheds is in your Cherenkov cone reconstruction; when your background simulation prices $NC\pi^0$ production, it is pricing rung one of this tower. The proton-decay search and the baryon spectrum are not neighboring topics; they are the bottom and the body of one ladder, and your analysis lives on both.

81 Status ledger of the Part

Table 23: Status ledger of Part IX. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it.

Claim	Grade	Fences / notes
$N = 3$; six flavors (54)	D(c)	GG-P2-N3's pincer at its declared grade; doubling is counting.
Toll hierarchy across the six	D(c)	GG-A9-SM's cascade codebook at its grade; this Part consumes, does not re-derive.
The graded tower (channel/label/lifetime grammar)	D + INT	Lifetimes and channels are data (PDG); the one-grammar reading is the framework's, priced rung by rung by GRIP-In.
Copies-not-cousins; identity per floor; width $\Leftrightarrow$ non-terminality	D(c)	Part III's theorem applied floor by floor; the no-second-zero-width prediction is a registered kill.

The ladder complete, the paper's local physics is done: the basin, its label, its cage, its immortality, its twin, and its tower — eight questions closed or fenced. What remains is history and ledger: where the wraps came from (Part X), and what each rearrangement of them costs the universe's books (Part XI).

Part X
The Birth of Baryons

The door that forbids one death permitted all births (Q10)

So far the paper has asked what the proton *is*. This Part asks the other question a complete account owes: where they all came from. The visible universe holds some 10^{80} protons and, to any measurable standard, no antiprotons — somewhere in the first instants, nature wrote matter a cheque that antimatter never cashed. This Part follows that transaction through the one door the stability theorem leaves open, and arrives at the paper's most satisfying single sentence: the law that forbids one proton's death is the law that permitted them all to be born.

82 The inventory question

Every Part so far has asked why the proton is what it is. This one asks why it is *here* — why, in a universe born as pure energy, there is any matter to have questions about.

Stated as a number, the mystery is small and stubborn. Compare the universe's baryons to its photons — the fossil light of the big bang against the fossil matter — and the ratio is

$$\eta_B = \frac{n_B}{n_\gamma} = 6.1 \times 10^{-10} \tag{55}$$

(Planck Collaboration, 2020): about one proton per 1.6 billion photons. That number is doubly strange. It is strange for being so *small* — matter is the trace contaminant of the cosmos, a part-per-billion impurity in a bath of light — and it is strange, far more deeply, for not being *zero*. A universe that began symmetric between matter and antimatter should have spent its matter: as it cooled, every baryon should have found an antibaryon, annihilated to photons, and left — by the standard freeze-out arithmetic (Kolb and Turner, 1990) — a residue near 10^{-18}: a billion times too little. Everything you have ever touched is made of the discrepancy. Q10, precisely put: what process wrote a one-part-per-billion *asymmetry* into the books before the great annihilation, so that when the smoke cleared, a residue of unpartnered protons remained?

Sakharov named the three conditions any answer must meet (Sakharov, 1967): baryon number must be violated (else the books stay balanced forever); C and CP must be violated (else every matter-making process runs equally in the mirror, and the books balance again); and the process must run out of equilibrium (else forward and reverse rates cancel the asymmetry as fast as it forms). Three locks on the door of existence. The Standard Model, remarkably, holds a key to each — and each key is too small: its CP violation, funneled through the single CKM phase, falls short of the required asymmetry by many orders of magnitude; and its electroweak transition is a smooth crossover, not the out-of-equilibrium slam the third condition wants. The standard theory knows *why* matter could exist; it cannot make *enough* of it. The status table of Part I marked this row honestly, and nothing in this Part erases the marking: the birth of baryons is imported here at its stated grade, not solved on this page.

83 The structural selection: in this geometry, the lepton door is the only door

What this paper *does* own is a sharpening that no standard treatment can offer. The literature holds a menu of baryogenesis mechanisms — GUT-boson decays, electroweak scenarios, leptogenesis, and their variants — and treats the choice as taste constrained by data. In the geometry of Part VI, the menu collapses under a structural rule:

> *Any mechanism that mints baryon number through* $\Delta B = \pm 1$ *operators is not suppressed in this framework; it is nonexistent. The only admissible baryon-number violation is the sphaleron door,* $\Delta B \in 3\mathbb{Z}$*, open above the electroweak scale. Therefore the asymmetry must be minted in a conserved-sector currency — as* $B-L$*, in the lepton sector — and converted to baryons at the door. Leptogenesis is not preferred here. It is forced.*

The classic GUT mechanism (Georgi and Glashow, 1974; Sakharov, 1967) minted baryons directly, in the decays of the same X, Y bosons that mediated proton decay — mechanism and menace were one coin, which is why the tank was built. In this geometry the coin is void on both faces: the winding selection rule that welds the proton's stability (T-P6-2) erases the $\Delta B = 1$ minting channel identically, at every temperature. What survives, and what alone survives, is the electroweak anomaly's own vertex ('t Hooft, 1976): above the electroweak barrier, sphaleron transitions (Kuzmin, Rubakov, and Shaposhnikov, 1985) shuffle baryon and lepton number freely along the one direction the anomaly permits — changing $B + L$, conserving $B - L$, in packets of three — and below the barrier the same vertex freezes at the e^{-372} of (48). The consistency sentence of Part VI now becomes a production requirement: to make baryons at all, nature had to make *lepton-sector asymmetry first*, while the door stood open, and let the door do the conversion. The proton's immortality and its nativity are two temperatures of one equation.

84 The chain, at its stated grade

The concrete chain is the CPT companion's, and this Part walks it exactly as its home declares it (Arisaka, 2026, P5-CPT) — one named input, one named conjecture, no upgrades issued here.
The mirror-sector heavy neutrinos of GG-P5-CPT's anatomy decay out of equilibrium in the early universe, at the TeV scale — the framework's lock scale, not a new one — with the CP asymmetry supplied by the ledger phases that paper derives from the descent's orientation. At TeV masses the asymmetry must be resonantly enhanced (the quasi-degenerate regime of Pilaftsis and Underwood, 2004), and the *resonance condition* is the chain's one named input, declared as such at home. The lepton asymmetry then survives washout and rides the open door: sphalerons convert the

accumulated $B-L$ into baryon number with the equilibrium partition

$$B \;=\; \frac{8N_f + 4N_H}{22N_f + 13N_H}\,(B-L) \;=\; \frac{28}{79}\,(B-L) \tag{56}$$

for three families and one Higgs doublet (Harvey and Turner, 1990) — the chemical-potential bookkeeping is walked in Appendix F, and the 28/79 is nothing but the door's exchange rate, fixed by counting the species standing in the marketplace. The conversion's transport normalization — the $K/2$ exponent in the washout compression — is the chain's one named conjecture (C-P5-C at home), and the chain's landing on the measured (55) is stated there with its honest window, factor-of-two resolution, dials declared. The yield is delivered to the cosmology paper (Arisaka, 2026, A10-Cosmos), where it feeds the inventory this paper's Part I quoted.

That is the whole import, and the fences stay up: a reader who wants the asymmetry's derivation audits GG-P5-CPT; a reader who wants its consumption audits GG-A10-Cosmos. What belongs to *this* paper is the two-sided consistency that neither neighbor could state alone, and it deserves its own paragraph.

Figure 22 compresses the chain of this Part into one line: the lepton-sector asymmetry, the one hot door, the partition, and the seal.

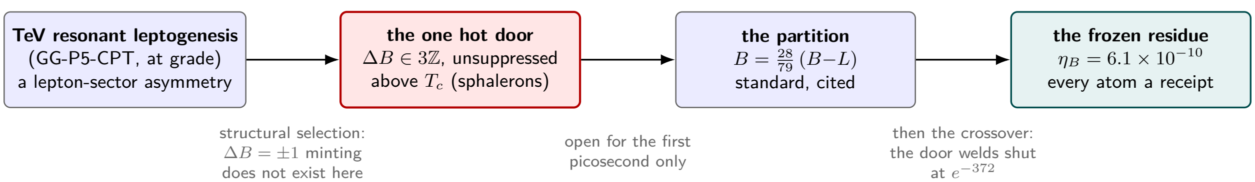


Figure 22: The birth chain of this Part in one line. The structural selection theorem says $\Delta B = \pm 1$ minting does not exist in this geometry, so whatever made the baryons had to make them from a lepton-sector asymmetry through the single $\Delta B \in 3\mathbb{Z}$ door — open, unsuppressed, for the hot first picosecond; partitioned by the standard 28/79 bookkeeping; frozen at $\eta_B = 6.1 \times 10^{-10}$ when the electroweak crossover welded the door shut at the 't Hooft price. The equation that forbids one proton's death is the equation that permitted all protons' births.

85 Every proton is a fossil of the door

Put Part VI and this Part side by side and read them as one statement about one exponent. Below the electroweak scale, the sphaleron weight $e^{-4\pi/\alpha_W} = e^{-372}$ welds the door: no proton decays, ever, anywhere — fifty years of watched water confirm it. Above the electroweak scale, the same expression, with its barrier submerged in the thermal bath, is order one: the door swings freely — and in the first picosecond, it *had* to swing, or the lepton-sector asymmetry would have died a curiosity and the universe would have annihilated to light. One coupling, one topology, two temperatures: the frozen reading is Q6, the fertile reading is Q10, and neither can be repealed without repealing the other. A skeptic who would remove the proton's immortality must explain why matter exists in the teeth of the annihilation catastrophe; a skeptic who would remove the

sphaleron door must find another lawful mint, and Part VI has closed every alternative in this geometry. The two questions the century kept in separate chapters — *why does matter persist?* and *why is there matter?* — are one question about one door, asked at two temperatures.
And so the Part's title sentence, now earned in full: every proton in your body, in the tank's water, in the farthest quasar, is a fossil — the frozen output of a door that opened once, while the universe was hot enough to hold it open, and then welded itself shut with the contents inside. The silence Super-Kamiokande records is the sound of the weld holding. The matter it is made of is the receipt.

For the reader in the tank. Your experiment usually describes itself as a search for proton decay. This Part invites a second description: a precision audit of the door's weld — and thereby, at one remove, of the only mechanism this geometry permits for your own existence. If Hyper-Kamiokande sees a decay, it does not merely falsify a stability theorem; it reopens Q10 from scratch, because the mint that made you could then not have been the lepton door alone. The two greatest questions your detector touches — whether matter is forever, and why it is here — are, in this framework, the same measurement.

86 Falsifier faces of the Part

F-P6-1, doing double duty. An observed proton decay kills T-P6-2 (Part VI) *and* orphans Q10: it would re-admit $\Delta B = 1$ minting and demolish the structural selection of §83. One event falsifies two Parts at once — the framework has deliberately left itself no fallback between them.

F-P6-3, sharpened cosmologically. An observed n–$\bar{n}$ oscillation would, beyond its Part VI kill, resurrect $\Delta B = 2$ ("post-sphaleron") baryogenesis as a live mechanism — a class this geometry forbids outright. Its observation is therefore a double kill here too.

The chain's own fences. The resonance condition and C-P5-C are GG-P5-CPT's registered items; if either fails at home, this Part's import fails with it, and the ledger below says so. What would survive such a failure: the structural selection itself (*some* $B-L$-first mechanism through the door), which rests only on Part VI.

87 Status ledger of the Part

History settled, one question remains — the framework's own, the newest on the list and the one held to the strictest register in the paper: what does a proton's rearrangement cost the universe's *other* ledger?

Table 24: Status ledger of Part X. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it.

Claim	**Grade**	**Fences / notes**
η_B, the catastrophe, Sakharov's conditions	D	Data and standard theory, cited; SM quantitative failure stated per literature.
Structural selection (leptogenesis forced, not preferred)	D(c)	Corollary of T-P6-2 at Part VI's grade: no $\Delta B = \pm 1$ mint exists; the door is unique.
The chain (resonant TeV leptogenesis $\rightarrow$ door $\rightarrow \eta_B$)	D(c)	GG-P5-CPT's, at its declared grade: one named input (resonance), one named conjecture (C-P5-C); consumed verbatim, upgraded nowhere.
Partition (56)	D	Equilibrium chemical-potential bookkeeping, Appendix F; standard, cited.
Two-temperature consistency (Q6 $\equiv$ Q10 at one door)	D(c)	This Part's own sentence, on Part VI's grade; the double-duty kills registered.

Part XI
The Information Charge

U$(1)_{Qi}$ for the proton: one rearrangement, one unit (Q11)

One face remains, and it is unlike the other ten: not a century-old question inherited from the field, but this framework's own — what does a proton's rearrangement cost the universe's *information* books? Because the claim is the youngest in the paper, it is held to the strictest register the cohort owns: the way to kill it is stated before the claim itself, and nothing in the ten Parts behind us leans on what follows.

88 The kill criterion, first

This Part carries the youngest claim in the paper and therefore opens in reverse order: with what would kill it, before what it says. The discipline is deliberate. Ten Parts of theorems and imports have earned the reader's trust at stated grades; this Part spends none of that trust, because its subject — the information charge U$(1)_{Qi}$ — is held by its home paper at *candidate* grade, kill criterion registered (Arisaka, 2026, A7-Qi4), and a candidate that borrows a theorem's tone is how frameworks rot. So, first, the registered kill, quoted in substance: *the Arisaka equation requires the four currents of every elementary boundary event to be locked; a demonstrated elementary event that updates the baryonic ledger without the corresponding locked informational unit — or at a different conversion factor — falsifies the equation.* That is F-P6-6, imported intact. Everything below is what the candidate says *if it lives.*

89 The Arisaka equation, restated for the proton

Part II carried the equation in; here is what it asserts, read with this paper's eyes. At every elementary boundary event, four currents move together or not at all:

$$\frac{J_E}{\mathsf{Q_B}} = J_e = J_B = J_{Qi}, \qquad \mathsf{Q_B} = \frac{2}{5}\frac{E_{\mathrm{Ryd}}}{K} = 0.1555 \text{ eV}, \tag{57}$$

energy, electric charge, baryon number, and information, locked through one conversion constant — the ledger constant $K = 35$ appearing once more, in its fourth cohort role. The claim's shape should now feel familiar, because it is the shape this whole paper has drilled: a conserved boundary quantity is not a substance but a *bookkeeping of readout events*, and (57) says the books are one book. The electric column and the baryonic column of that book, Parts III and VI showed, are windings — exact, quantized, unfakeable. U$(1)_{Qi}$ is the framework's proposal that the book has a fourth column of the same character: every elementary rearrangement in which a baryon participates — every capture, every binding, every readout update in which the wrapped configuration changes state —

debits the energy ledger by $\mathsf{Q_B}$ per unit and credits the information ledger by exactly one unit. Not *about* $\mathsf{Q_B}$; exactly $\mathsf{Q_B}$, or the equation is dead. Candidates that specify their own execution are the only candidates worth registering.

90 What it means for the proton — and what it does not license

Read (57) against the paper's earlier results and the proton acquires a closing characterization. Part III made it the Ground Geometric Attractor: matter's floor. Part VI made its baryon number a winding: matter's permanence. This Part's candidate, if it lives, adds: the proton is the *page* of the boundary's ledger — the stable substrate whose rearrangements are the countable, durable entries of the information column. Only a zero-width, winding-protected object can anchor a permanent record; everything else in the baryon tables dissolves in 10^{-10} seconds or less, taking its entries with it. In this reading, the fact that every durable structure in the universe — every nucleus, molecule, mineral, memory — is written *on baryonic matter* is not substrate chauvinism but bookkeeping necessity: the information column requires pages that do not burn, and Part VI built the only fireproof page in the spectrum. *The proton is not only matter's terminus; it is the ledger's paper.*

Two calibrations put the constant on a human scale, both computed and both carried at strictly this Part's grade. At room temperature, Landauer's bound prices the cheapest possible erasure of one bit at $k_B T \ln 2 = 0.0179$ eV; the Arisaka unit is

$$\frac{\mathsf{Q_B}}{k_B T_{300} \ln 2} \;=\; 8.7 \tag{58}$$

— an order-one multiple of the thermodynamic floor at the temperature where chemistry computes, not parachuted in from some distant scale. And the workhorse energy quantum of biological information processing, ATP hydrolysis at ≈ 0.32 eV, is almost exactly *two* Arisaka units ($0.32/0.1555 = 2.0$). The home paper builds its bioenergetic bridge on such coincidences at candidate grade; this paper neither extends nor endorses that bridge — it records the two ratios as what they are, calibrations that make the constant tangible for the reader in the tank whose photomultiplier pulses are, one level down, ATP-priced information events about baryons.

What the candidate does *not* license, stated bluntly because candidates attract freight: no claim that "the universe is a computer"; no rate limit on human technology (the equation prices elementary boundary events, not engineered logic built redundantly atop them); no modification to any result of Parts I–X, all of which stand at their own grades if $\mathrm{U}(1)_{Qi}$ dies tomorrow. The dependency arrow points one way only.

91 The experimental face, honestly sized

Where could F-P6-6 actually bite? The honest answer is that the decisive experiment does not yet exist, and this Part says so rather than gesturing at one. The equation's natural testing ground is the mesoscopic frontier where single-event calorimetry meets single-particle control — trapped-ion and single-atom thermodynamics, nanocalorimetry approaching the $k_B T$ scale, single-nucleon-resolved chemistry — where the locked-currents claim becomes, in principle, a measurable question: does an elementary baryonic rearrangement carry its fixed informational tariff, or can the columns be decoupled? The framework's own contribution to experimental design is the lock's rigidity: (57) permits no partial credit, so any clean decoupling at any single event scale kills it — a binary target of exactly the kind Part VI gave the tank. Until such an experiment matures, this Part's register stays where its home put it: candidate, alive, specified, and waiting.

92 Status ledger of the Part

Table 25: Status ledger of Part XI. Grades as in Table 3. Three columns: the claim, the grade it is carried at, and the fences or notes that bound it. The ledger is here so that the standing of the whole Part can be read down one column instead of reconstructed from the text, and so that no claim of the Part is left without a grade beside it. Part XI's last row is the one that matters to the rest of the paper: nothing upstream leans on this Part.

Claim	**Grade**	**Fences / notes**
Arisaka equation (57); Q_B	CAND	GG-A7-Qi4's, at GG-A7-Qi4's registered grade; kill criterion quoted first (F-P6-6).
Ledger's-page reading of the proton	INT	This Part's framing of the candidate; adds no claim beyond (57) + Parts III/VI.
Calibrations (58), ATP $\approx 2Q_B$	D	Arithmetic, session-verified; carried as calibration only; the bioenergetic bridge remains GG-A7-Qi4's at its grade.
Independence of Parts I–X from this Part	D	The dependency arrow stated; nothing upstream leans here.

Eleven questions are now closed or fenced. What remains is the weighing — significance, uniqueness, the debts collected in one registry, with the objections answered at full length near the end (Part XV) — and then the walk back out of the mine, in plain English, to say what half a century of silence taught.

Part XII
Discussion

Significance, uniqueness, falsification, and the open problems — the objections are answered at full length in Part XV

The physics is done; the weighing begins. This Part steps back from the derivations and asks the questions a careful reader will ask of the whole: what has actually been established, and at what grade? How does this account differ — structurally, not rhetorically — from the other roads the century built? What observation would kill it, and when will we know? And what does it still owe? The answers are collected in one place, without inflation, because a paper that keeps eleven promises owes its reader a single page where all eleven receipts can be checked.

93 What has been done, weighed soberly

Eleven questions were put on the table in Part I; the honest way to close is to say, without inflation, what happened to each. Two were answered by *theorems of this paper*: the sharp mass and exact charge by the ground-attractor theorem (T-P6-3), and the immortality-and-law pair by the obstruction theorem and the $\mathbb{Z}_3$-lock (T-P6-1, T-P6-2) — the latter completing a stability theorem the cohort had carried as conditional since its Standard-Model paper. Three were answered by *imports consumed at their proved grades*: the six flavors by the family theorem, the twin's existence and descent by the toll competition and the gate, the birth of baryons by the CPT companion's chain through the door this paper's own theorem leaves open. Three were answered by *readings, graded as such*: the spin as label (INT, with its promotion registered), confinement as branch selection (INT, behind a Clay-grade fence), the free quark's absence upgraded halfway — its *impossibility* is now a corollary of a theorem (C-P6-1), its *costliness* remains QCD's. And one is a *candidate carried at candidate grade*, kill criterion first (the information charge). Nothing on the list was answered by adjustment; no parameter was tuned anywhere in these pages, because the framework put none at this paper's disposal.

The deepest single result, the author believes, is the smallest-looking: the center identity $B = t/3$. Baryon number's fractional content was sitting inside the color group the whole century — a finite rotation, invisible to every algebra-level search for a gauged B — and once it is seen, the rest follows with almost embarrassing economy: one setting of one existing dial breaks the symmetry, evicts the executioners, splits the Higgs, and writes the winding. If this paper is remembered for one page, it should be that one.

94 Uniqueness, as structural contrast

The program's discipline is contrast without polemic: state what each alternative structure *is*, and where the present one differs, and stop. Four contrasts locate this paper.

Against classical unification. Grand unified theories share this paper's premise — the forces unify, and quark and lepton sit in one representation — and differ in one locational fact: their unification lives on the boundary, so their X, Y bosons are four-dimensional particles and proton decay is mandatory. Fifty years of silence have pushed the simplest such models out and their successors to ever higher scales. Here unification is a bulk fact; the X, Y are real and boundary-absent; and the same geometry that removes them writes the conservation law the silence measures. The experiment that was mortal danger to one architecture is standing confirmation of the other — and remains mortal danger to *this* one through F-P6-1, which is how the contrast stays honest.

Against the Standard Model's accident. The Standard Model conserves baryon number by bookkeeping luck: nothing imposes it, and the accident survives no extension. The framework's B is imposed — gauged in the bulk, Stueckelberg-massive, topologically realized — which is the difference between a habit and a law. The observational wedge between the two readings is exact: the accident permits ΔB-violating operators at dimension six and merely prices them by an unknown scale; the law forbids them at every dimension. Any decay signal at any rate, however far beyond current reach, distinguishes the two forever.

Against orbifold unification. The nearest relatives of Part VI's construction are the orbifold GUTs (Kawamura, 2001), which taught the field that boundary conditions can do the work of Higgs sectors — splitting doublet from triplet and suppressing decay by geography. The present construction inherits that insight and differs in three structural respects: the twist is not a chosen parity assignment per multiplet but the unique center point of the existing hypercharge line (no intrinsic-parity freight); the protection is not geographic suppression but an exact winding charge (a selection rule, not a distance); and the reflection sector is not an engineering choice but is fixed by the CPT companion's theorem, tying the construction to the cohort's antiparticle result. Whether these differences are virtues is for the reader; that they are differences is arithmetic.

Against the ten-dimensional route to anomaly freedom. The mainstream's price for anomaly freedom was fixed in 1984: ten dimensions, supersymmetry, and a specific enormous gauge group (Green and Schwarz, 1984); and in the heterotic, GUT-descended constructions that dominated string phenomenology, baryon number remained accidental and approximate. One string lineage — the intersecting-brane Standard Models (Ibáñez et al., 2001) — does gauge $\mathrm{U}(1)_B$, and what it finds independently corroborates this paper's mechanism: the boson arrives Green–Schwarz-massive and the proton is protected, though generically only in perturbation theory. The contrast is therefore three clauses about price, not mechanism: the dominant unification roads carry no exact baryon number at all; where strings do gauge it, the protection arrives GS-massive exactly as here, but atop ten dimensions, supersymmetry, and extended objects, and only perturbatively exact; and this framework keeps Lee–Yang's gauging, pays the anomaly bill at six dimensions through the BI-6 inflow, uses no supersymmetry and no string-like objects, and delivers protection exact to all orders — the topological $\Delta B \in 3\mathbb{Z}$ door its single, load-bearing exception. Part VII keeps the full record, convergence included.

Against the confinement mechanisms. The dual-superconductor picture, the center-vortex picture, and the lattice's N-ality lore (Greensite, 2011) are accounts of *how* the Yang–Mills vacuum generates a confining force — competing descriptions of the disorder, each with real numerical successes, none yet promoted to a proof. This paper is not a competitor on that ground and claims nothing there: the dynamical half of confinement remains QCD's, held here at one named hypothesis from a theorem (T-P6-4). The structural contrast lies one level down, at a question the mechanism literature does not pose: *why* $\mathbb{Z}_3$*?* Why should triality, of all quantum numbers, be the arbiter of who is caged — why does the center decide who is confined, when confinement holds, and where the disorder lives (§39), three lattice-verified roles that the standard account inherits as facts about SU(3) representation theory and does not further explain? Here the three roles are one fact seen three times, because the center is not bookkeeping on field space but the holonomy of a real cycle: the singlet rule is its closure condition (§45), the cage is the impossibility of closing a third of a turn (C-P6-1), and the immortality is the impossibility of unwinding a whole one (T-P6-2). No mechanism paper claims the free quark is a grammatical impossibility; this paper claims exactly that, at the lock's stated grade, and hands the claim its own kill switch (F-P6-2).

Against the quotient as footnote. That the faithful gauge group of the Standard Model is the quotient $[\mathrm{SU}(3)_C \times \mathrm{SU}(2)_L \times \mathrm{U}(1)_Y]/\mathbb{Z}_6$ has been known to model builders for decades — and has sat in the literature as fine print, a true remark about which group one should have written down, carrying no dynamics. The framework's structural difference is that the fine print is load-bearing (§55): the quotient's $\mathbb{Z}_3$ is the statement $B - 2Y \in \mathbb{Z}$, which is the sentence that parks the descent's holonomy at the center point (47); the same three shared phases are the triangle of Figure 16; and the triangle's electromagnetic shadow, $Q + B \in \mathbb{Z}$ fragment by fragment (39), welds the fractional quark charges — treated since 1974 as the unification's aesthetic bonus (Georgi and Glashow, 1974) — to the baryon winding that keeps the proton alive. A remark about representations in one architecture; the hinge joining Q2, Q5, and Q6 in the other. Whether the promotion is a virtue is for the reader; that the two standings differ is arithmetic.

95 The falsification table

The paper's kills, collected with their current experimental anchors and, where they exist, their dates. The table is the contract of §5, now fully priced.

One property of this table deserves notice: rows one through four are *null results that grow stronger every year an experiment runs*. A framework whose sharpest tests are ongoing silences is in the unusual position of being tested continuously, at megaton scale, every day — and of owing its community that fact plainly, which Part VI's closing section was written to do.

Table 26: The falsification table of GG-P6-Proton. Each row: one observation that kills the stated result outright. "Decidable" marks rows where planned experiments will materially extend reach on a stated timescale. Six rows, each naming one observation, the result it would kill, and the anchor or horizon against which it stands. The right column is what makes the table usable rather than rhetorical: it gives the current bound and, where an experiment will materially extend reach, the decade in which it does so.

ID	Killing observation	Kills	Anchor / horizon
F-P6-1	One proton decay, any channel	T-P6-2; and reopens Q10 (Part X)	$> 2.4 \times 10^{34}$ yr (Takenaka et al., 2020); Hyper-K/DUNE/JUNO extend an order of magnitude by ∼2040
F-P6-2	One confirmed free fractional charge (any source, incl. QGP)	C-P6-1; wounds T-P6-2	eighty-year null (Navas et al., 2024); standing
F-P6-3	n–$\bar{n}$ oscillation	T-P6-2 ($\Delta B = 2$); and Part X's mechanism class	free $> 0.86 \times 10^8$ s (Baldo-Ceolin et al., 1994); ESS proposal extends
F-P6-4	Proton–antiproton asymmetry (mass, $\lvert q\rvert/m$, moment magnitude); H/$\bar{\text{H}}$ charge anomaly	the dihedral reflection (Part VI); conjugate readout	16 ppt (Borchert et al., 2022); 0.71 ppb (Ahmadi et al., 2016); improving
F-P6-5	Long-range force coupled to B	Stueckelberg structure of $U(1)_B$	Eöt-Wash Be/Ti (chosen to maximize the baryonic difference): $\eta = (0.3 \pm 1.8) \times 10^{-13}$ (Wagner et al., 2012); MICROSCOPE near 10^{-14}; standing
F-P6-6	Elementary baryonic ledger update without the locked informational unit	the Arisaka equation (at its home's grade)	experiment not yet mature (§91)

96 The debt registry

Every open item this paper carries, consolidated. The registry follows the cohort's convention: a debt is named where incurred, listed here, and either discharged in a later paper of the cohort or carried honestly forever. None of the six is a conjecture of principle; each is a bounded computation or reading.

D-P6-1 — DISCHARGED here. The reading of the deployed descent's reflection on complex representations: the realization paper's own text supplies the conjugation twist, $C = (\theta \mapsto -\theta) \circ B$, at theorem grade via T-P5-C2 (§57). Recorded per the registry convention; no residue remains.

D-P6-2 (= pin R2), narrowed here. The holonomy-integrality pin, now named to its clause: descent coefficients are Hopkins–Singer-integral in this framework (Arisaka, 2026, A9-SM; Appendix D), which quantizes the Wilson-line parameter to the six-point lattice. Outstanding: the X_4-level derivation of the holonomy's class.

D-P6-3. The spinor-level derivation that the terminal basin's boundary readout carries $j = \frac{1}{2}$ (§32) — one computation shared with the sister paper's D-P3-4; the two registries discharge together.

D-P6-4, restated as a scoreboard here. (a) Branch uniqueness — delivered as T-P6-4's corollary, conditional on the gap hypothesis $\widehat{G}$. (b) The area law — delivered at theorem-structure grade on $\widehat{G}$ plus the lock (§41); the functional tightening of Steps 3–4 is the named formal residual. (c) The pure number σ/Λ^2 — OPEN: the wall computation owed; target and kill window printed in §43. (d) The Lüscher coefficient — CLOSED, unconditionally (§42). (e) The thermal face — partial: center/Potts universality inherited for the pure-gauge transition; quantitative targets owed with (c). The single deep residual is $\widehat{G}$ itself — the gap, the Clay-hard core — whose location is priced (33) and whose existence this paper does not claim.

D-P6-5 (= pin R3), narrowed here. The warped zero-mode profiles at fractional winding. The *mechanism* — bosons priced by the Laplacian, unpaired chiral floors massless by the absence of a partner — is now exhibited in Appendix G; what remains owed is the quantitative profile computation in the warped metric with the GDOS radial functions.

D-P6-6. The completeness of the constitutional label inventory, on which the uniqueness leg of T-P6-3 conditions (§20): the statement that the boundary's exact labels are exactly the winding pair and the spinor label, referred to GG-A1-Constitution's axiom set.

97 Status ledger of the Part

This Part makes no new physics claims; its ledger is the falsification table (§95) and the registry (§96); the objections are answered at full length in Part XV, each by citation into the Parts that carry the load. The paper-wide claim-status ledger — every numbered result with its grade and location — is Part XIV's opening table.

The weighing is done, and the scales read as this Part has recorded them: so much derived, so much conditional, so much honestly owed — nothing hidden, nothing inflated. What remains is not analysis at all. It is the walk back out of the mine: the century, the tank, and the theorem, retold in the plain language they have earned — and the closing words belong, as they should, to the author, who first went underground in 1979 and has, in a sense, been walking back out ever since.

Part XIII
Conclusions

The century, the tank, and the theorem — in plain English

98 Why the questions waited a century

The eleven questions of this paper are not exotic. A child can ask most of them — *why doesn't it break? why doesn't it run down? why is every one the same?* — and the century that built quantum mechanics, quantum field theory, and the Standard Model never stopped being asked. Why, then, did they wait?

Because each generation's tools answered a *finer* question instead. Scattering resolved structure, so the century asked about structure — form factors, partons, distributions — and answered magnificently. Field theory computed rates, so the century asked about rates. What no tool before the present framework was built to ask was the child's own question, which is about *standing*: what kind of thing is a proton, that the storm inside it should present one face forever? The answer this paper has assembled — a Ground Geometric Attractor of a landscape, carrying a winding of a compact geometry — required pieces the century acquired slowly and separately: the attractor grammar, the open-system boundary, the center of the color group, the topology of a circle no one believed was there. None of the pieces is exotic either. What waited a century was the *assembly*.

99 The view from the last page

Stand at the end and look back; the eleven questions have become one another.

The proton has one exact mass because it is the floor of its landscape, and floors do not come in variants (Q1). Its charge cancels the electron's because both are entries of one five-by-five matrix that must sum to zero (Q2). Its spin will not decompose because a label is not a sum (Q3). Its quarks cannot leave because a third of a wrap is not a state (Q4, Q5). It cannot die because no operator can change the number of wraps (Q6), and that is a law, not a habit, because the winding is gauged into the geometry (Q7). Its twin dies in fifteen minutes because the twin sits a hair's-breadth up-slope with one narrow gate open — and survives forever in nuclei because binding re-landscapes the gate (Q8). Its six flavors are three families said twice, and its excited copies crumble on schedule, each at the price its labels set (Q9). It exists at all because the one door its conservation law leaves open stood open in the hot first picosecond, converting a lepton-sector asymmetry into every baryon there is (Q10). And — if the youngest claim in this paper survives its own kill criterion — its rearrangements are the durable entries of the boundary's information ledger, making it not only matter's terminus but the page the universe writes on (Q11).

One ground attractor. One winding. One door. Eleven faces.

100 The one fact, and where it sits

Step back once more, and the eleven faces resolve into a single object with a single name. The proton is the Ground Geometric Attractor of the baryonic stratum — the GGA, the deepest admissible valley of the landscape of color-singlet, baryon-number-one matter. That is not one more result in the list; it is the fact of which every entry in the list is a reading. The mass is the depth of that ground basin; the charge is its exact label; the immortality is its empty exit-channel set, gauged shut; the identity of every proton with every other is what GGA-hood *means*. The century found these one at a time and filed them under separate headings — mass, charge, stability, universality — and this framework's claim is that they were always four windows onto one ground state.

And that ground state is not the end of a story but the beginning of one. The electron is the GGA of the leptonic stratum; the proton is the GGA of the baryonic one; and between the two of them they are the ground on which the whole Chain of GRIP-Out is built (§9). Bind them and the atomic stratum opens — hydrogen, then the periodic table; let atoms bond and the molecular stratum opens — water, then the amino acids, the proteins, ATP, RNA, DNA, and every rung above, each its own GGA, each standing on the one below. This is the picture the capstone paper (Arisaka, 2026, A11-Origin) draws in full, and it is the reason a study of one particle can claim to touch the heart of the framework: the proton is where that grand cascade — the one that runs, in the end, all the way to an observer able to state it — comes to rest at the bottom and begins to build. It is the foundation stone of the material world, and a foundation stone earns its name by never moving.

That is the deepest reason the watch under the mountain matters. A search for proton decay is usually described as a search for a rare event; in this framework it is something larger — a test of whether the foundation of all stable matter is exactly, and not merely almost, eternal. The man who first went underground in 1979 to watch the proton die has spent a career at that foundation, and the answer this paper offers him, and the generation now on the catwalk above the water, is that the foundation holds: the proton is the Ground Geometric Attractor at the bottom of the Chain of GRIP-Out, the still point on which the whole tower of the world is built.

101 The conclusions, in plain English

For the reader who skipped the mathematics, an honest summary in ten sentences. Most of everything's weight is not stuff but settled storm: your bathroom scale reads the energy of gluon fields that have found their resting place. That resting place is unique, which is why every proton in the universe is exactly alike — they are not similar objects but one mathematical object, read out everywhere. The proton's charge matches the electron's to twenty-one digits because both are lines of a single code, not because two accidents agree. Nobody has ever pulled a quark out of a proton, and nobody ever will, for the same reason nobody will show you a third of a knot. The proton has never been seen to die, though we built cathedrals underground to watch; this paper derives that the watching must stay silent — matter's number is wound into the shape of space, and windings do not unwind. The neutron, the proton's near-identical twin, dies in about fifteen minutes on its own but lives forever inside atoms, and that one detail is why chemistry — and you

— can exist. The heavier copies of the proton all crumble instantly; the universe is built from the single rung of the ladder that cannot. The matter in the universe is the frozen residue of a door that stood open for the first trillionth of a second and then sealed itself; every atom is a receipt from that transaction. If the proton is ever seen to decay, this entire framework is wrong, and the experiments best placed to prove it wrong are the direct descendants of the tank this story began with. That is not a weakness of the framework; it is the whole point of having one.

102 The fifty-year arc

A doctoral student went underground in 1979 to build a machine for watching protons die, because the best theory of the age had made their death its safest prediction. He spent six years on the tank, the optics, the electronics (Arisaka et al., 1985); the field expected a flash within a year or two of first light. The flash never came. The machine, refusing to waste its silence, heard the sun instead, and then a dying star (Hirata et al., 1987), and founded an astronomy; its successors pushed the proton's silence past 10^{34} years; and the question the tank was named for went unanswered for the length of a career.

Forty-eight years after that student first walked into the mine, this paper — his — returns the answer: the flash cannot come, and the silence was the discovery. The prediction that built the tank mistook the location of the executioners; the geometry keeps them in the bulk, and writes the proton's number where no operator can reach it. The tank was right the whole time — right in a way its builders could not have stated, because the theorem that says so needed half a century of other results first.

To the student now standing where he stood — on the catwalk at Hyper-Kamiokande, in the cavern at DUNE — the closing message of this paper, from its author to you: keep watching. Your silence is a measurement, the sharpest ever made of the deepest law this framework contains. And if one night the water flashes where no muon entered — then this paper dies, physics is reopened at its foundations, and yours will be the most important eyes in the history of the subject. Either way, the watch is not a vigil over a settled question. It never was.

Part XIV
Technical Appendices

The reference apparatus — abbreviations, the paper-wide claim-status ledger, the empirical anchor table — followed by the arithmetic companions, Appendices A through G, each written so that a reader with one sheet of paper can verify the load-bearing computations by hand

A good workshop earns its keep by keeping every tool where a working reader can find it; that is this Part's only job. The body of this paper has emphasized the theorem chain; this Part supplies the technical apparatus that supports each step. It is organized into two groups, on the pattern of the cohort's Standard-Model paper. The *reference* apparatus comes first: the abbreviations, the paper-wide claim-status ledger (every numbered result, its grade, and its fences, in one table), and the empirical anchor table (every measured value the paper quotes, with its source — all arithmetic on these values was verified by machine at drafting). The *constructive* appendices follow: the arithmetic companions to Parts III through X — the transmutation walk (A), the spin ledger (B), the string (C), the lock (D), the neutron (E), the door (F), and the chirality-protection exhibit (G) — each written so that a reader with one sheet of paper can verify the load-bearing computations by hand, and each accompanied, where the algebra is dense, by the physics intuition that translates it into a mental picture. The objections a hostile specialist would raise are answered, reader by reader, in the Common Objections Part that follows these appendices; the annotated references close the paper after that.

103 Abbreviations

104 The claim-status ledger

Every numbered claim of the paper, its grade, and its fences — the honesty apparatus in one place. Grades: **D** derived; **D(c)** derived conditionally (fences named); **INT** interpretation, named; **CAND** candidate, kill criterion registered.

Table 27: The abbreviations used in this paper, set two-up: the program's own names on the left of each pair and the standard physics abbreviations on the right. The grid is arranged this way because the list is short enough to take in at a glance and long enough to be worth not hunting through, and because the program's own names are the ones a reader coming from outside will not already know.

GG-6	Grand Geometric (Theory)	QCD	quantum chromodynamics
GGA	Ground Geometric Attractor	QED	quantum electrodynamics
GA	Geometric Attractor (way station)	GGA	ground geometric attractor
GDOS	Geom. Dynamics of Open Systems	SM	Standard Model
GFF	the free-energy functional	GUT	grand unified theory
GSSB	geometric spontaneous symmetry breaking	CKM	Cabibbo–Kobayashi–Maskawa
GRIP-In	the in-flow descent pricing	CPT	charge–parity–time
MSMF	Max. Symmetry, Min. Freedom (axiom)	QGP	quark–gluon plasma
BI-6	the modified Bianchi identity	EIC	Electron–Ion Collider
D-P6-n	registered debt n of this paper	PDG	Particle Data Group
F-P6-n	registered falsifier n of this paper	UCN	ultracold neutron
GS	Green–Schwarz (inflow)	EP	equivalence principle

Table 28: The claim-status ledger of GG-P6-Proton. Every named claim in the paper, in one list: the item, a compressed statement of it, the grade it is carried at, and the Part that owns it together with its fences. The grade column is the honest part, separating what is derived from what is derived conditionally, what is an interpretation, and what is a candidate with a kill criterion registered. It is meant to be read whole before any single row is leaned on.

Item	Statement (compressed)	Grade	Home; fences
T-P6-1	Baryon number is not realizable as any per-multiplet constant plus hypercharge; gauged $B-L$ forbids no dimension-six decay operator	D	Part VI; exact linear algebra
Center identity	$B = t/3$ exactly on every fragment; $e^{2\pi iB} = z$	D	Part VI
Lock-point uniqueness	$z = W(2)$ on the hypercharge line; sole quantized holonomy satisfying the spectrum's three demands	D	Part VI; quantization = D-P6-2
T-P6-2	The $\mathbb{Z}_3$-lock: winding lattices $t/3 + \mathbb{Z}$; floors carry B; H2 discharged; H1 corollary; Yukawa selection rules	D(c)	Part VI; D-P6-2, D-P6-5; floor survival = GG-A9-SM claim
Dihedral closure	Untwisted reflection forbids the lock; C-twisted closes as $\mathbb{D}_3$; reflection = $B \to -B$	D	Part VI; closure = T-P5-A + deployed $C = (\theta \to -\theta)\circ B$; D-P6-1 discharged
Anomaly ledger	Six coefficients exact; two survivors to BI-6 inflow; $[\mathrm{SU}(2)_L]^2 B$ the sole physical door, $\Delta B \in 3\mathbb{Z}$	D	Part VI; H3 as received

continued overleaf

The claim-status ledger, continued.

Item	Statement (compressed)	Grade	Home; fences
T-SM-60.1 completed	Proton absolutely stable; $\Delta B = \pm 1, \pm 2$ forbidden to all orders	D(c)	Part VI; H3 + D-P6-2 + D-P6-5
T-P6-3 (i)	Existence of the stratum's floor	D	Part III
T-P6-3 (ii)	Uniqueness of the floor	D(c)	Part III; D-P6-6
T-P6-3 (iii)	Zero width (terminality)	D(c)	Part III; the B-leg at Part VI's grade
T-P6-3 (iv)	Identity of all readouts	D	Part III
Mass pricing	Transmutation from $\alpha_s^{-1}(M_Z) = \pi e$; one-loop walk; pure number from lattice	D(c)	Part III; registration at GG-A9-SM's grade
Charge table	$Q = T_3 + Y$ from the embedding; $Q(p) = -Q(e)$ as algebra	D	Part III
Charge/spin rigidity	Winding and representation labels admit no drift	D(c)	Parts III–IV; fiber reading at sister paper's grade
Spin custody	Total = boundary label; shares = bulk ledger, scheme-dependent	INT	Part IV; promotion = D-P6-3
T-P6-4	Conditional area law: gap hypothesis $\widehat{G}$ + lock $\Rightarrow F \geq \sigma_{\min} L$; tube; N-ality asymptotics	D(c)	Part V; on $\widehat{G}$ + (A1)(A2) + T-P6-2's grade; Higgs escape closed by C-P6-1; tightening a named residual
Goldstone-counting test	Flux-tube Lüscher coefficient $-\pi/12$ from exactly two transverse modes; spatial extra dimensions at σ-scale excluded	D	Part V; unconditional given the tube; lattice-confirmed
Branch-selection uniqueness	Color-singlet branch the unique stable attractor	D(c)	Part V; corollary of T-P6-4 + T-P6-3 on $\widehat{G}$; GSSB grammar gloss remains INT
C-P6-1	No boundary readout carries fractional winding; the free quark is not a state	D(c)	Part V; at T-P6-2's grade
QGP custody	Bulk color mobility; integer readout preserved	INT + D	Part V; the null record is data
Twin competition	$m_n - m_p$ = toll (+2.5) + EM (−1.0)	D	Part VIII; lattice-cited; inputs at GG-A9-SM's grade
Gate descent	β-decay as GRIP-In transit; lifetime walk 914 $\to\sim$ 878 s	D(c)	Part VIII; standard EW computation cited

continued overleaf

The claim-status ledger, continued.

Item	**Statement (compressed)**	**Grade**	**Home; fences**
Sanctuary condition	Binding closes the gate; bound-n stability	D	Part VIII
Ladder grammar	Lifetime = price of cheapest open descent; labels decide	D + INT	Part IX; widths are data
Six flavors	$N = 3$ (import) doubled	D(c)	Part IX; GG-P2-N3's fences
Structural selection	$\Delta B = \pm 1$ minting nonexistent; leptogenesis forced	D(c)	Part X; at T-P6-2's grade
Birth chain	Resonant TeV leptogenesis → door → η_B	D(c)	Part X; GG-P5-CPT's named input + conjecture
Door partition	$B = \frac{28}{79}(B-L)$	D	Part X; standard, cited
Arisaka equation for the proton	Locked currents; $\mathsf{Q_B}$ per rearrangement; ledger's-page reading	CAND + INT	Part XI; GG-A7-Qi4's grade; F-P6-6 first

105 The empirical anchor table

Every measured value quoted in the paper, with its source. All arithmetic performed on these values was verified by machine at drafting; the final digit-for-digit collation of each entry against the current PDG print is the standing pre-release checklist item for this paper's next revision.

Table 29: The empirical anchors of GG-P6-Proton. Every empirical number this paper leans on, with the value exactly as quoted and the source it is quoted from. Nothing here is derived and nothing is rounded to suit an argument; where a bound rather than a value is what exists, the bound is what appears. The table is the paper's exposure to measurement, gathered in one place so that it can be checked against the literature in a single pass.

Quantity	**Value as quoted**	**Source**
m_p	938.272 088 MeV, zero width	(Navas et al., 2024)
$m_n - m_p$	1.293 MeV	(Navas et al., 2024)
μ_p	$2.79\,\mu_N$ (first structure, 1933)	(Frisch and Stern, 1933; Navas et al., 2024)
Hydrogen neutrality	$\lesssim 10^{-21}\,e$	(Bressi et al., 2011)
Antihydrogen charge	< 0.71 ppb	(Ahmadi et al., 2016)
$\bar{p}/p$ charge-to-mass	16 ppt agreement	(Borchert et al., 2022)
Eötvös parameter $\eta(\mathrm{Be},\mathrm{Ti})$	$(0.3 \pm 1.8) \times 10^{-13}$	(Wagner et al., 2012)
$\tau/B(p \to e^+\pi^0)$	$> 2.4 \times 10^{34}$ yr (90% CL)	(Takenaka et al., 2020)
Super-K exposure	0.37 Mton yr	(Super-Kamiokande, 2024)
$\tau_{n\bar{n}}$ (free)	$> 0.86 \times 10^8$ s	(Baldo-Ceolin et al., 1994)
τ_n (bottle)	877.75 ± 0.28 s	(Gonzalez et al., 2021)

continued overleaf

The anchor table, continued.

Quantity	Value as quoted	Source
τ_n (beam)	887.7 ± 2.2 s	(Yue et al., 2013)
m_u, m_d ($\overline{\text{MS}}$)	2.16, 4.67 MeV	(Navas et al., 2024)
m_b, m_c (thresholds)	4.18, 1.27 GeV	(Navas et al., 2024)
$\alpha_s(M_Z)$ (world)	0.1180(9)	(Navas et al., 2024)
$\Lambda^{(3)}_{\overline{\text{MS}}}$ (4-loop, lattice-matched)	≈ 340 MeV	(Navas et al., 2024)
String breaking r_b	≈ 1.24 fm	(Bali et al., 2005)
0^{++} glueball (pure gauge)	1.71 GeV	(Morningstar and Peardon, 1999)
T_c (pure SU(3), first order)	≈ 270 MeV	(Greensite, 2011)
$\sigma/\Lambda^2_{\overline{\text{MS}}}$ (target, D-P6-4(c))	1.67	arithmetic (§43)
$\Delta\Sigma$	≈ 0.25–0.35	(Ashman et al., 1988; de Florian et al., 2014)
String tension σ	$(440\text{ MeV})^2$	(Bali, 2001)
Regge slope α'	$\approx 0.9\text{ GeV}^{-2}$	(Bali, 2001)
T_c (crossover)	156.5 ± 1.5 MeV	(Bazavov et al., 2019)
n–p splitting (lattice QCD+QED)	$+2.52$ (quark), -1.00 (EM) MeV	(Borsanyi et al., 2015)
g_A; $\lvert V_{ud}\rvert$; G_F	1.2756; 0.9737; $1.166 \times 10^{-5}\text{ GeV}^{-2}$	(Navas et al., 2024)
B(deuteron)	2.224 MeV	(Navas et al., 2024)
$\Delta(1232)$: mass, width	1232, 117 MeV	(Navas et al., 2024)
Ω^-: lifetime	0.8×10^{-10} s	(Navas et al., 2024; Barnes et al., 1964)
η_B	6.1×10^{-10}	(Planck Collaboration, 2020)
$k_B T_{300} \ln 2$ (Landauer)	0.0179 eV	arithmetic
ATP hydrolysis	≈ 0.32 eV	standard biochemistry; carried as calibration only

The appendices follow: the transmutation arithmetic (A, for Part III), the spin ledger (B, Part IV), the string (C, Part V), the lock (D, Part VI), the neutron (E, Part VIII), and the door (F, Part X).

A The transmutation arithmetic, step by step

This appendix complements §21: every number quoted there, derived at the blackboard pace. A reader who works through these two pages owns the mechanism that prices 99% of their own body weight.

A.1 Solving the one-loop equation

Start from (10), $\mu\, d\alpha_s/d\mu = -(b_0/2\pi)\, \alpha_s^2$. Separate and integrate between Λ and μ:

$$\int \frac{d\alpha_s}{\alpha_s^2} = -\frac{b_0}{2\pi} \int d\ln\mu \quad\Longrightarrow\quad \frac{1}{\alpha_s(\mu)} = \frac{b_0}{2\pi} \ln\frac{\mu}{\Lambda}, \tag{59}$$

where the integration constant has been *named*: Λ is defined as the scale at which the inverse coupling would vanish. Inverting gives both forms of (11). Two observations worth a margin note. First, (59) says the inverse coupling is *linear in* $\ln\mu$ — the straight lines on every unification plot, including the one in Part I's inheritance map. Second, $d\Lambda/d\mu = 0$ by construction: differentiate $\Lambda = \mu\, e^{-2\pi/b_0\alpha_s(\mu)}$ and use (10); the explicit μ-dependence and the implicit one through α_s cancel identically. That cancellation is what "renormalization-group invariant" means, and it is why Λ is physics rather than convention.

A.2 The walk, digit by digit

Input: the GG-A9-SM registration $\alpha_s(M_Z) = 1/(\pi e) = 0.11710$ at $M_Z = 91.188$ GeV; thresholds at $m_b = 4.18$ GeV, $m_c = 1.27$ GeV (Navas et al., 2024); $b_0(n_f) = 11 - \frac{2}{3}n_f$.
Step 1 ($n_f = 5$, $b_0 = 23/3$). The exponent is

$$\frac{2\pi}{b_0\,\alpha_s(M_Z)} = \frac{6.2832}{7.6667 \times 0.11710} = 6.999,$$

so $\Lambda^{(5)} = 91.188\, e^{-6.999}$ GeV $= 91.188 \times 9.13 \times 10^{-4} = 83.3$ MeV. Note what happened: the input contained nothing small, and the output is three orders below the seam. The hierarchy is the exponential's doing — no dial exists anywhere in this step.
Step 2 (cross m_b; $n_f = 4$, $b_0 = 25/3$). First run to the threshold within $n_f = 5$: $\alpha_s(m_b) = 2\pi/[7.6667 \ln(4.18/0.0833)] = 0.2093$. Then re-solve for the four-flavor invariant:

$$\Lambda^{(4)} = 4.18\, e^{-6.2832/(8.3333\times 0.2093)} = 4.18\, e^{-3.602} = 113.9 \text{ MeV}.$$

The invariant *jumps* at the threshold — each n_f band has its own Λ; continuity is in α_s, not in Λ.
Step 3 (cross m_c; $n_f = 3$, $b_0 = 9$). $\alpha_s(m_c) = 2\pi/[8.3333 \ln(1.27/0.1139)] = 0.3128$;

$$\Lambda^{(3)} = 1.27\, e^{-6.2832/(9\times 0.3128)} = 1.27\, e^{-2.232} = 136 \text{ MeV}.$$

By here the coupling is 0.31 and climbing fast; one more decade of descent and perturbation theory is over — which is not a failure but the arrival: the strong regime where the basin lives.

A.3 What one loop misses, stated plainly

The walk above is pedagogy-grade transport, and it *understates* Λ: the two-loop coefficient is large and positive in its effect on the invariant, and the world's four-loop, lattice-matched determination is $\Lambda^{(3)}_{\overline{\text{MS}}} \approx 340$ MeV (Navas et al., 2024) — roughly 2.5 times the one-loop value, in a quantity that lives inside an exponential. The lesson to carry: the *mechanism* (a scale from no scale, hierarchy from an exponent) is exact and loop-order-independent; the *digits* belong to high-order transport plus the lattice, and this paper quotes them from there. Precision claims about (12) itself are GG-A9-SM's to defend, at GG-A9-SM's declared register, with the QD completion carrying the residual; nothing in T-P6-3 leans on them.

A.4 The pure number, and the toll ledger

The lattice computes, from the coupling and quark masses alone, the full light-hadron spectrum to percent accuracy (Dürr et al., 2008); in invariant units this fixes $m_p/\Lambda^{(3)}_{\overline{\rm MS}} \approx 938/340 \approx 2.8$ — the pure number of (14), nature's own, no dials. The Higgs toll ledger, for completeness (PDG $\overline{\rm MS}$ current masses): $m_u = 2.16$ MeV, $m_d = 4.67$ MeV, so $2m_u + m_d = 8.99$ MeV $= 0.96\%$ of m_p; the neutron's extra down-quark swaps this to $m_u + 2m_d = 11.50$ MeV, a $+2.51$ MeV valence-toll difference against which the proton's larger electromagnetic self-energy competes — the 1.293 MeV residual of that competition is Part VIII's opening number. Weigh yourself, divide by one hundred: that is what the Higgs pays through the valence masses; its full sigma-term response is a few kilograms more (§21.5). The rest is the storm, settled in its basin.

A.5 The closure arithmetic, digit by digit

Companion to §21.4: the five-percent prediction, at blackboard pace. The sensitivity first. Hold μ fixed in $\Lambda = \mu\, e^{-2\pi/b_0\alpha_s}$ and differentiate the logarithm:

$$\frac{\partial \ln\Lambda}{\partial \ln\alpha_s} = \alpha_s \cdot \frac{\partial}{\partial\alpha_s}\left(-\frac{2\pi}{b_0\alpha_s}\right) = \frac{2\pi}{b_0\alpha_s} = \frac{6.2832}{7.6667\times 0.1180} = 6.95$$

at the M_Z seam ($n_f = 5$). The input deviation is $\delta\alpha_s/\alpha_s = (0.11710 - 0.1180)/0.1180 = -0.763\%$; linearized, $\delta\Lambda/\Lambda = 6.95\times(-0.763\%) = -5.30\%$. The linearization overstates the shift, because the walk re-matches at each threshold and b_0 grows as flavors decouple ($23/3 \to 25/3 \to 9$), shrinking the downstream sensitivity. Re-running the entire one-loop walk of §21.3 with $\alpha_s(M_Z) = 0.11710$ in place of 0.1180 gives $\Lambda^{(3)} = 136.2$ MeV against 142.5 MeV: a ratio of 0.9555, i.e. -4.45%. Hence

$$m_p^{\rm pred} = 938.272\times 0.9555 = 896.5\ \text{MeV}\quad (\text{linearized bound: } 888.6\ \text{MeV}),$$

the five-percent closure of (17). Two more identities the reader can check on one sheet. The pure number factorizes through the string tension: with $\sqrt{\sigma} = 440$ MeV and $\Lambda^{(3)}_{\overline{\rm MS}} = 340$ MeV,

$$\frac{m_p}{\sqrt{\sigma}} = \frac{938.3}{440} = 2.13,\qquad \frac{\sigma}{\Lambda^2} = \left(\frac{440}{340}\right)^2 = 1.675,\qquad 2.13\times\sqrt{1.675} = 2.76 = \frac{938}{340},$$

which is (21). And the sigma ledger of §21.5: $43.7 + 28.6 = 72.3$ MeV $= 7.7\%$ of m_p — the proton's full Higgs response, roughly eight times the valence tolls. Every number in this subsection is machine-verified in the paper's companion suite.

B The spin ledger arithmetic

Companion to Part IV: the bookkeeping behind §30, at blackboard pace.

B.1 The two sum rules, and where their entries live

The Jaffe–Manohar ledger (27) is built in the infinite-momentum frame with light-cone gauge $A^+ = 0$: there, and only there, "gluon spin" ΔG is the first moment of a measurable polarized density, which is why the polarized-scattering program quotes it. The Ji ledger (28) trades manifest partonic meaning for gauge invariance: J_q and J_g are matrix elements of the gauge-invariant angular-momentum tensor, accessible through the second moments of generalized parton distributions, $J_q = \frac{1}{2}\int dx\, x\,[H_q(x,0,0) + E_q(x,0,0)]$. The two orbital entries differ by the *potential angular momentum* $L_q^{\rm JM} - L_q^{\rm Ji}$ — the field-torque term — which is calculable and generically non-zero. Neither ledger is wrong; they answer differently-posed questions, and the difference is itself a well-defined physical quantity. That is what "the parts are convention" means in practice: not vagueness, but precision that refuses to be unique.

B.2 The anomaly shift, priced

The singlet axial charge measured in polarized DIS is (29): $a_0 = \Delta\Sigma - (3\alpha_s/2\pi)\,\Delta G$. At $\alpha_s = 0.35$ (a few GeV^2), $3\alpha_s/2\pi = 3(0.35)/6.283 = 0.167$; with $\Delta G \approx 0.4$ the shift is $0.167 \times 0.4 = 0.067$ — comparable to the entire experimental uncertainty band of (25). The measured "quark spin" is thus, at the anomaly level, partly gluonic: even the ledger's cleanest-looking line is a mixture under the hood. (Historically this term powered a decade of attempts to blame the whole EMC result on ΔG; the measured gluon polarization (de Florian et al., 2014) is too small for that rescue, and the modern resolution is the one in the main text: no rescue was needed, because nothing was missing.)

B.3 The remainder, with today's central values

Take $\Delta\Sigma = 0.30$ and the RHIC-era $\Delta G \approx 0.2$ over the measured range: the Jaffe–Manohar ledger then assigns $L_q + L_g = \frac{1}{2} - \frac{1}{2}(0.30) - 0.2 = 0.15$ — a third of the proton's spin in orbital motion, awaiting the EIC's direct tomography. The reader is invited to update this line when the EIC numbers arrive; the framework's pre-registered expectation (Part IV) is that the entries will move, the total will not, and no scheme will become canonical.

C The string arithmetic

Companion to Part V: five numbers a student should compute once by hand.

C.1 Sixteen tonnes

The string tension (31) as a force: $\sigma = (0.440\ \text{GeV})^2 = 0.194\ \text{GeV}^2$; multiplying by the conversion $1\ \text{GeV} = 5.068\ \text{fm}^{-1}$ gives $\sigma = 0.981\ \text{GeV/fm}$. In SI units,

$$F \;=\; \frac{0.981 \times 1.602 \times 10^{-10}\ \text{J}}{10^{-15}\ \text{m}} \;=\; 1.57 \times 10^5\ \text{N} \;=\; 16.0\ \text{tonnes-force},$$

distance-independent. Sixteen tonnes between two points too small to have ever shown a size, at any separation, forever. Committing this number to memory is the fastest known cure for underestimating the strong interaction.

C.2 The Regge cross-check

The rotating-string model prices the tension independently: a straight string of tension σ spinning at its ends' light-speed limit satisfies $J = \alpha' M^2 + \text{const}$ with slope $\alpha' = 1/(2\pi\sigma)$. The measured Regge slope of the light-meson trajectories, $\alpha' \approx 0.9\ \text{GeV}^{-2}$, inverts to $\sigma = 1/(2\pi \times 0.9) = 0.177\ \text{GeV}^2 = (421\ \text{MeV})^2$ — within five percent of the lattice value (31) from a one-line classical model. The hadrons have been telling us they are strings-with-endpoints since the 1960s; the trajectories were the first flux-tube evidence, decades before the lattice drew the tube.

C.3 Where the string surrenders

The break-point: budding a light quark–antiquark pair costs roughly twice a constituent-quark dressing, 2×0.48 GeV ≈ 0.96 GeV, so $r_{\text{break}} \approx 0.96/0.981 \approx 1$ fm at the crude estimate — and the lattice's directly-observed breaking sits at $r_b \approx 1.24$ fm, where the stored energy reads $\sigma r_b \approx 1.22$ GeV (Bali et al., 2005). Beyond one femtometer the vacuum finds it cheaper to manufacture matter than to stretch geometry: every "jet" in every collider event display is this arithmetic, iterated down a cascade. The cage does not leak; it franchises.

C.4 The crossover radius

Where does the string take over from the Coulomb term? Set the magnitudes of the two terms of (30) equal: $r_c = \sqrt{(4/3)\,\alpha_s\,\hbar c/\sigma}$; with $\alpha_s \approx 0.3$ this gives $r_c \approx 0.28$ fm — and by 1 fm the linear term outweighs the Coulomb term six to one. The proton's interior straddles this radius, which is why neither term alone describes it.

C.5 The Lüscher correction, and what it counts

The universal string correction (32) evaluates to $-\pi/12 \times 197.3\ \text{MeV fm}/r$: -103.3 MeV at 0.5 fm, -51.7 MeV at 1 fm, -34.4 MeV at 1.5 fm. Its coefficient is $-(D_\perp)\pi/24$ with $D_\perp$ the number of massless transverse modes: one additional spatial direction at the QCD scale would give $-3\pi/24 = -\pi/8$ — a fifty percent shift, -77.5 MeV at 1 fm — which lattice string spectroscopy excludes. This arithmetic is the entire engine of the Goldstone-counting test (§42): the QCD string, vibrating, counts the spatial dimensions and finds exactly three.

D The lock arithmetic

Companion to Part VI: the exact computations behind the obstruction, the operator audit, the anomaly ledger, and the door's price. Everything here is finite arithmetic over the rationals; the reader is warmly encouraged to redo all of it on one sheet of paper.

D.1 The obstruction, in the general per-irrep form

The text proved Theorem 53.1 inside the **10**; here is the bookkeeping with both constants live. Demand $B = \alpha_r + \beta Y$ with α_r free per irrep $r \in \{\overline{\mathbf{5}}, \mathbf{10}\}$:

$$\begin{aligned} \mathbf{10}: &\quad \alpha_{10} + \tfrac{\beta}{6} = \tfrac{1}{3}\ (Q), \quad \alpha_{10} - \tfrac{2\beta}{3} = -\tfrac{1}{3}\ (u^c), \quad \alpha_{10} + \beta = 0\ (e^c), \\ \overline{\mathbf{5}}: &\quad \alpha_{\overline{5}} + \tfrac{\beta}{3} = -\tfrac{1}{3}\ (d^c), \quad \alpha_{\overline{5}} - \tfrac{\beta}{2} = 0\ (L). \end{aligned}$$

The **10** block alone is overdetermined and inconsistent ($\beta = \frac{4}{5}$, $\alpha_{10} = \frac{1}{5}$, then $\frac{1}{5} + \frac{4}{5} = 1 \neq 0$), so the system fails before the $\overline{\mathbf{5}}$ is even consulted. By contrast, targeting $B - L$ (values $\frac{1}{3}, -\frac{1}{3}, -1$ on Q, u^c, e^c and $-\frac{1}{3}, +1$ on d^c, L... with the lepton-number sign conventions of the text) the same five equations *are* consistent, with the unique solution

$$B - L = \tfrac{1}{5}\left(X + 4Y\right), \qquad X(\mathbf{10}) = +1, \quad X(\overline{\mathbf{5}}) = -3$$

— the SO(10) spinor's branching charge, recovered here as the *only* Abelian direction of this form. The moral in one line: the solvable charge is the wrong one, and the right charge is not solvable.

D.2 The decay-operator audit

The four classic dimension-six operators, with all fields incoming left-handed Weyl (a daggered field contributes the negative of its charge):

Table 30: The lowest-dimension baryon-number-violating operators, with the baryon number each carries and the value of baryon number minus lepton number. The right column is the point: every one of them has that combination equal to zero. These are the operators a proton decay would have to use, and the Part's argument is about why this geometry does not supply them.

operator	B	$B-L$
$Q\,Q\,Q\,L$	+1	0
$u^c\,u^c\,d^c\,e^c$	−1	0
$Q\,Q\,(u^c)^\dagger(e^c)^\dagger$	+1	0
$Q\,L\,(u^c)^\dagger(d^c)^\dagger$	+1	0

Every row: maximally B-charged, exactly $B-L$-neutral. A gauged $B-L$ — however exact — forbids none of them; the winding charge of T-P6-2 forbids all of them. This table is why H2 had to produce genuine B, and why Theorem 53.1's second sentence is load-bearing rather than decorative.

D.3 The anomaly sums, term by term

Per family, left-handed Weyl content with multiplicities (color × weak): Q: 6, u^c: 3, d^c: 3, L: 2, e^c: 1. Dynkin index $T(\text{fund}) = \frac{1}{2}$.

$[\mathrm{SU}(3)_C]^2\,\mathrm{U}(1)_B$*:* colored fields only, weighted by weak multiplicity:

$$\underbrace{2\cdot\tfrac{1}{2}\cdot\tfrac{1}{3}}_{Q}+\underbrace{\tfrac{1}{2}\cdot(-\tfrac{1}{3})}_{u^c}+\underbrace{\tfrac{1}{2}\cdot(-\tfrac{1}{3})}_{d^c}=\tfrac{1}{3}-\tfrac{1}{6}-\tfrac{1}{6}=0.$$

$[\mathrm{SU}(2)_L]^2\,\mathrm{U}(1)_B$*:* doublets only, weighted by color: $\underbrace{3\cdot\tfrac{1}{2}\cdot\tfrac{1}{3}}_{Q}+\underbrace{1\cdot\tfrac{1}{2}\cdot 0}_{L}=\tfrac{1}{2}$. **The door.**

$[\mathrm{U}(1)_Y]^2\,\mathrm{U}(1)_B$*:* $6\cdot(\tfrac{1}{6})^2\cdot\tfrac{1}{3}+3\cdot(\tfrac{2}{3})^2\cdot(-\tfrac{1}{3})+3\cdot(\tfrac{1}{3})^2\cdot(-\tfrac{1}{3})=\tfrac{1}{18}-\tfrac{4}{9}-\tfrac{1}{9}=-\tfrac{1}{2}$. (Green–Schwarz-absorbed; no Abelian instantons, hence inert.)

$[\mathrm{U}(1)_B]^2\,\mathrm{U}(1)_Y$*:* $6\cdot(\tfrac{1}{3})^2\cdot\tfrac{1}{6}+3\cdot(\tfrac{1}{3})^2\cdot(-\tfrac{2}{3})+3\cdot(\tfrac{1}{3})^2\cdot\tfrac{1}{3}=\tfrac{1}{9}-\tfrac{2}{9}+\tfrac{1}{9}=0$.

$[\mathrm{U}(1)_B]^3$*:* $6\cdot\tfrac{1}{27}-3\cdot\tfrac{1}{27}-3\cdot\tfrac{1}{27}=0$. $\mathrm{U}(1)_B$*–grav*^{2}*:* $6\cdot\tfrac{1}{3}-3\cdot\tfrac{1}{3}-3\cdot\tfrac{1}{3}=0$.

Four zeros without assistance; two halves, equal and opposite, for the inflow to absorb. The reader who has just done these six sums has personally verified the cleanest half of the stability theorem.

D.4 The price of the door

The topological vertex changes B by $N_{\mathrm{gen}}\,n=3n$ and carries the tunneling weight $e^{-16\pi^2/g_2^2}=e^{-4\pi/\alpha_W}$. Evaluating at the electroweak scale with $\alpha^{-1}(M_Z)=127.93$ and $\sin^2\theta_W=0.2315$:

$$\alpha_W=\frac{\alpha}{\sin^2\theta_W}=\frac{1}{29.6},\qquad \frac{4\pi}{\alpha_W}=372,\qquad e^{-372}\approx 10^{-162}.$$

For calibration: the universe is $\sim 4\times 10^{17}$ seconds old and Super-Kamiokande watches $\sim 10^{34}$ protons; a rate bearing the factor 10^{-162} loses to that exposure by more than a hundred orders of magnitude. At temperatures above the electroweak barrier the exponential is absent altogether — sphaleron transitions are unsuppressed — which is the regime Part X inhabits. One exponent, evaluated twice, separates the frozen present from the fertile first picosecond.

D.5 The integrality pin, named

Pin R2 — the quantization of the holonomy parameter c to integers of period six, on which the uniqueness scan of §56 runs — is not free-standing: the cohort already owns an integrality apparatus. The Standard-Model paper's quantum-deviation rationals are, in its own words, the *Hopkins–Singer descent integrality coefficients* on the relevant boundary strata (Arisaka, 2026, A9-SM): descent data in this framework is integrally quantized, not continuously adjustable. Applied to the present case, the Wilson-line parameter is a descent coefficient on the compact cycle, and integrality against the spectrum's smallest hypercharge ($\tfrac{1}{6}$, the quark doublet's) quantizes it to the six-point lattice the scan walks. What remains of D-P6-2 after this naming is the X_4-level derivation — exhibiting the holonomy's class in the same integral-cohomology bookkeeping that prices the QD rationals — which is bounded, technical, and owed; what is no longer open is *whether* the parameter is quantized, or by what clause.

E The neutron arithmetic

Companion to Part VIII: the splitting, the lifetime, and the sanctuary condition, each at blackboard pace.

E.1 The splitting, decomposed

Table 31: The neutron–proton mass difference, contribution by contribution, with the source of every number named. The valence toll difference and the full lattice quark-mass part agree inside their errors; the electromagnetic part pulls the other way; and the sum sits on the measured splitting within the quoted uncertainty. The table is set out this way because the cancellation between the two large terms is what makes the small answer worth anything.

contribution	value (MeV)	source
valence toll difference $m_d - m_u$	$+2.51$	PDG current masses (Navas et al., 2024)
full QCD (quark-mass) part	$+2.52 \pm 0.29$	lattice (Borsanyi et al., 2015)
electromagnetic part	-1.00 ± 0.16	lattice+QED (Borsanyi et al., 2015)
sum	$+1.5 \pm 0.3$	
measured $m_n - m_p$	$+1.293$	(Navas et al., 2024)

Two remarks. The agreement of rows one and two — naive current-mass difference against the full nonperturbative computation — is leading-order behavior a student should expect but never assume: in a *difference* of isospin twins, the storm's contribution cancels almost perfectly, and what survives is the toll ledger. And the two effects' opposite signs are structural, not accidental: the toll term must favor a heavier neutron (the d costs more), the electromagnetic term must favor a heavier proton (only it is charged); the window for chemistry exists because two unrelated pieces of the codebook straddle zero.

E.2 The lifetime, walked

The tree-level rate for $n \to p\, e^- \bar{\nu}_e$:

$$\Gamma \;=\; \frac{G_F^2\, |V_{ud}|^2\, m_e^5\, (1 + 3g_A^2)\, f}{2\pi^3}, \tag{60}$$

with inputs, all measured elsewhere and none adjustable here: $G_F = 1.166 \times 10^{-5}$ GeV^{-2} (muon decay); $|V_{ud}| = 0.9737$ (superallowed nuclear β-decays); $g_A = 1.2756$ (neutron decay correlations); and $f = 1.6887$, the dimensionless three-body phase-space integral over the $Q = 0.782$ MeV doorway — the number that carries Sargent's fifth power. Assemble: $(1 + 3g_A^2) = 5.882$;

$$\Gamma = \frac{(1.166 \times 10^{-5})^2 (0.9737)^2 (5.110 \times 10^{-4})^5 (5.882)(1.6887)}{2\pi^3} = 7.20 \times 10^{-28} \text{ GeV},$$

and with $\hbar = 6.582 \times 10^{-25}$ GeV s,

$$\tau_{\text{tree}} = \frac{\hbar}{\Gamma} = 914 \text{ s}.$$

Electroweak radiative corrections and recoil effects, computed to high precision in the literature, reduce this by roughly four percent: $\tau \approx 878$ s, against the bottle's 877.75 ± 0.28 (Gonzalez et al., 2021). For the Sargent intuition, compare the muon: same gate, $Q = 105.7$ MeV; the phase-space ratio $(105.7/0.782)^5 \approx 4 \times 10^{10}$ accounts, by itself, for the leap from the neutron's minutes to the muon's microseconds. The gate has one price list; the doorways differ.

E.3 The sanctuary condition

A neutron bound in a nucleus (A, Z) can only decay if the books balance:

$$Q_{\text{eff}} \;=\; \big[M(A,Z) - M(A,Z{+}1)\big] - m_e \;>\; 0,$$

the parent–daughter mass difference having already absorbed every binding-energy shift. In the deuteron: the descent would break the bond (2.224 MeV) against a doorway of only 0.782 MeV — closed, by 1.44 MeV of margin. Every stable isotope is a solution of this inequality's failure, which is why the valley of nuclear stability is a *valley*: its walls are drawn by where the gate's books stop balancing. The reader who wants the framework in one sentence here: the gate force never changed; the landscape under it did.

F The door bookkeeping

Companion to Part X: the catastrophe, and the exchange rate of the door.

F.1 The annihilation catastrophe, sized

In a matter-symmetric universe, nucleons and antinucleons track their equilibrium abundance until the annihilation rate falls behind the expansion rate. The standard freeze-out arithmetic (Kolb and Turner, 1990) — annihilation cross-section of hadronic size, freeze-out near $T \approx 20$ MeV — leaves a relic of

$$\frac{n_B}{n_\gamma}\Big|_{\text{symmetric}} \;\sim\; 10^{-18},$$

against the measured 6.1×10^{-10} (Planck Collaboration, 2020): a shortfall of nearly nine orders of magnitude, *and* no mechanism for the survivors to be matter rather than a matter–antimatter patchwork. The catastrophe is the cleanest statement of why Q10 needs an asymmetry written *before* the annihilation, not a survival strategy during it.

F.2 The exchange rate: where 28/79 comes from

Above the electroweak scale, with sphalerons and every Standard-Model Yukawa and gauge interaction in equilibrium, the species' chemical potentials are not independent: each fast process imposes one linear relation. Solving the full set for N_f families and N_H Higgs doublets — the classic bookkeeping of Harvey and Turner (1990) — expresses the frozen-out baryon number in terms of the conserved $B - L$:

$$B \;=\; \frac{8N_f + 4N_H}{22N_f + 13N_H}\,(B-L) \;\xrightarrow{N_f=3,\;N_H=1}\; \frac{28}{79}\,(B-L).$$

The structure deserves one sentence of feeling: the numerator and denominator are census figures — counts of who holds weak charge, who holds hypercharge, who couples to whom — and the fraction is simply the marketplace's equilibrium exchange rate between the lepton-sector currency the chain mints and the baryonic currency the universe keeps. Roughly a third of the deposited $B-L$ emerges as baryons; the rest remains in the lepton books, where the cosmic neutrino background holds it still.

F.3 The chain's landing, cited not claimed

For the reader assembling the full pipeline: the CPT companion's chain delivers its lepton asymmetry with one named input and one named conjecture, the partition above converts it, and the landing against (55) is stated at the home paper's honest resolution (Arisaka, 2026, P5-CPT). This appendix adds no digits to that statement — it exists so that the two standard links this paper *does* vouch for, the catastrophe and the exchange rate, are on the table with their arithmetic visible.

G The chirality-protection exhibit

Companion to Part VI, narrowing pin R3 (D-P6-5): *why* the twist lifts the scalar and vector floors while the chiral fermion floors survive with their fractional winding labels intact — the mechanism, exhibited; the quantitative warped profiles remain the debt's outstanding content.

G.1 Scalars and vectors: mass by Laplacian

For a boson on the compact cycle, the four-dimensional mass of a mode is read directly from the compact Laplacian: a component whose twisted periodicity shifts its winding lattice to $w \in t/3 + \mathbb{Z}$ has $m_w^2 \ni w^2/R_\theta^2$, and a lattice with no $w = 0$ point has no massless floor — full stop. This is the entire doublet–triplet mechanism of §56 in one line: the triplet's lattice misses zero by a third of a unit, the doublet's contains zero, and the X, Y vectors sit with the triplet. No boundary condition need be engineered per field; the arithmetic of the lattice does the splitting.

G.2 Chiral fermions: mass by pairing, not by winding

A fermion is different in exactly one structural respect, and everything hangs on it: *a four-dimensional fermion mass is not an eigenvalue but a marriage.* A Dirac mass term couples a left-handed mode to a right-handed partner; no partner, no mass, whatever energies are in play — the protection the Standard Model itself uses to keep its fermions light below the electroweak scale. On the descent's interval, the chirality projection (Part II) removes the would-be right-handed partner of each zero-mode floor at the boundary: the floor is *structurally single.* The twist now shifts the floor's θ-dependence to a fractional winding $e^{iw\theta}$ — but a phase is not a partner. The Laplacian eigenvalue w^2/R_θ^2 sits in the *paired* tower, where it lifts vector-like KK levels exactly as it lifts scalars; the unpaired chiral floor has no mass term to receive a contribution, and persists — carrying its fractional winding as a conserved label rather than an energy. That is the asymmetry T-P6-2 leg (ii) uses: the twist prices what can be priced (bosons, paired towers) and labels what cannot (chiral floors). The quantitative statement — the explicit floor profiles in the warped metric, with the GDOS tower's radial functions — is the remaining content of D-P6-5, deferred to a later treatment with its home machinery.

Part XV
Common Objections and Responses

The strongest objections a particle theorist, an experimentalist, a lattice practitioner, a string theorist, or a philosopher of science is most likely to raise on first reading — answered, with pointers into the paper

A paper that claims to close the proton's oldest questions — including a derivation that the proton cannot decay, offered by the man who built the first detector to watch it decay — will be met, rightly, with skepticism from every quarter. This Part collects seventeen objections, grouped by the background of the reader most likely to raise each, together with an extended response. They are collected from the hostile-review tradition of the cohort, and they are not strawmen: they are the questions the author has actually been asked, sharpened. Where the honest answer is "not yet," the response says so and points to the debt registry (§96) and the claim-status ledger (Table 28), which record exactly which claims are theorems, which are conditional, and which are readings or candidates. The test of a framework is not that it deflects every question, but that it knows which questions it has answered and which it has not.

H The law and the lock

Objection 1 (O-P6-1) (the skeptical experimentalist)
"You have not explained proton stability; you have moved the decay machinery to a bulk where nothing can be tested."

Response. The opposite, twice. First, the bulk placement is not a hiding move but a corollary: the same twist that lifts the X, Y bosons off the boundary is the twist that produces the observed Higgs sector (Part VI) — deny the placement and you must re-solve doublet–triplet splitting by other means. Second, and decisively for an experimentalist: the framework is *more* exposed than its predecessors, not less. A grand unified theory whose predicted lifetime is excluded retreats in scale and survives; F-P6-1 forbids decay at every rate, so any signal, ever, at any exposure, kills this framework outright. Moving the machinery to the bulk did not remove the theory from the laboratory; it removed the theory's escape hatch.

Objection 2 (O-P6-2) (the anomaly purist)
"Baryon number cannot be gauged; the anomalies forbid it. This has been settled since the 1970s."

Response. What the 1970s settled is a statement about a smaller theory: the anomalies of the *Standard Model's field content alone* forbid a massless, anomaly-free gauged B in four dimensions

— and Part VII's record shows the field drawing exactly that conclusion, correctly. Part VI's ledger pays exactly that bill rather than evading it: the six mixed coefficients are computed exactly (Appendix D); four vanish; the two survivors are absorbed by the BI-6 Green–Schwarz inflow (hypothesis H3, at its home paper's grade); and the Stueckelberg mass removes the massless mediator while keeping the rigid selection rule exact. The folk impossibility is not contradicted; it is priced, and the price is six dimensions rather than new fermions.

Objection 3 (O-P6-3) (the model-building skeptic)
"The $\mathbb{Z}_3$ point is a choice dressed as a derivation. You put the twist where you needed it."

Response. The scan of §56 is the answer in table form. The candidate holonomies on the hypercharge line are quantized — there are finitely many — and the three demands that GG-A9-SM's spectrum already makes (the Standard-Model group unbroken; a light doublet; no light triplet) eliminate every quantized point except the lock and its conjugate, which differ only by $B \to -B$. The only genuine "choice" is the same discrete boundary data by which the construction has a parity at all — and the reflection sector is then fixed by the CPT companion's theorem T-P5-A, not chosen (§57). What remains open is quantization itself (pin R2, named to the descent-integrality apparatus in Appendix D), and the ledger says so in place.

Objection 4 (O-P6-4) (the orbifold-GUT veteran)
"This is orbifold unification with new vocabulary. Kawamura did it in 2001."

Response. The lineage is acknowledged and cited where it is real (§94): orbifold unification taught the field that boundary conditions can do the work of Higgs sectors, and this construction inherits that insight. The three structural differences listed there are checkable statements about the constructions, not marketing: the twist is not a chosen parity assignment per multiplet but the unique center point of the existing hypercharge line; the protection is not geographic suppression of decay operators but an exact winding charge — a selection rule, not a distance; and the reflection sector is not an engineering choice but the CPT companion's theorem. A reader who checks the three and finds them cosmetic should say so with the constructions side by side; the paper welcomes exactly that comparison.

Objection 5 (O-P6-5) (the electroweak theorist)
"Sphalerons violate baryon number, so your 'exact' law is not exact."

Response. Exactness here is an operator statement: every *local operator* with $\Delta B \notin 3\mathbb{Z}$ vanishes identically, to all orders. The sphaleron is not an operator but a topological transition, quantized in units of three, unsuppressed only above the electroweak crossover and welded shut below it by the 't Hooft price $e^{-4\pi/\alpha_W} \sim 10^{-162}$. And the exception is load-bearing, not embarrassing: Part X needs precisely this door open, precisely then — the door that forbids one proton's death is the door that permitted all protons' births. A law with exactly one topological exception that turns out to be the origin of matter is not a leaky law; it is a well-designed one.

Objection 6 (O-P6-9) (the GUT model builder)

"Gauged $B-L$ would have been simpler and is standard. Why insist on B?"

Response. Simpler, standard, and useless for the question. $B-L$ is indeed the combination the algebra permits — Theorem T-P6-1 derives exactly that near-miss, with the textbook SO(10) charge appearing in the proof — but every dimension-six proton-decay operator *conserves* $B-L$ (the audit is tabulated in Appendix D). An exact $B-L$ lets every one of them stand. A framework that stops at $B-L$ protects nothing the tank measures; the entire point of the obstruction theorem is that protecting the proton requires precisely the charge the algebra refuses, which is why the discharge had to be topological.

Objection 7 (O-P6-10) (the quantum-gravity folklorist)

"Quantum gravity violates all global symmetries; your protection cannot survive the Planck seam."

Response. The folk theorem concerns *global* symmetries — accidents with no gauge structure behind them — and it is precisely why the Standard Model's accidental B inspires no confidence at high scale. The present B is not global-accidental: it is the rigid residual of a *gauged*, Stueckelberg-massive $\mathrm{U}(1)_B$, realized topologically as a winding. Gravity is not known, by any argument in the folk theorem's family, to violate gauge-descended selection rules; wormholes do not eat windings. This objection, pressed against the old accident, was decisive — Part VII records it doing its work for fifty years; pressed against the lock, it dissolves. The difference between the two cases is exactly what Q7 asked.

Objection 8 (O-P6-13) (the string theorist)

"Intersecting-brane models gauged baryon number with a Green–Schwarz-massive boson twenty-five years ago. Your mechanism is theirs, minus the ultraviolet consistency of string theory."

Response. The convergence is real, and this paper cites it rather than hiding it (§68; Ibáñez et al., 2001): the intersecting-brane Standard Models do gauge B, GS-massive, proton-protecting in perturbation theory. Three differences carry the weight, and each is checkable. First, the price: ten dimensions, supersymmetry, and extended objects there; a six-dimensional bulk and the BI-6 inflow here, with neither. Second, the exactness: brane instantons generically violate the brane-world B non-perturbatively, whereas the winding protection here is exact to all orders with the single topological $3\mathbb{Z}$ door. Third, the status: in the brane constructions the gauged B is a byproduct of the stack structure; here it is the founding axiom, and the paper derives its boundary realization rather than inheriting it. As for ultraviolet consistency: the framework's anomaly freedom is exactly the content of GG-A3-BI6, cited as H3 at its stated grade — the reader is invited to audit that ledger, not to take ten dimensions on authority.

I The readings and the twin

Objection 9 (O-P6-6) (the lattice practitioner)
"The confinement Part claims credit for QCD's hardest problem."

Response. It claims none; its first section is a fence built to be quoted against it (§34), and the Clay-grade mathematics is named as open in exactly the place a lattice reader would look. What is claimed at theorem grade is narrower and different: the free quark's non-existence as a *boundary state* (C-P6-1) — a statement about readouts and windings, not about the mass gap. The measured string tension, the crossover temperature, and every quantitative fact of confinement are quoted from the lattice with their citations; the Part adds a reading of *why* the branch selection goes the way it goes, graded INT — a registration now partly paid: the conditional area-law theorem T-P6-4 stands one named gap hypothesis from the full claim (§41), and the field's mechanisms are compared honestly, lattice results first, in Table 8.

Objection 10 (O-P6-7) (the philosopher of science)
"The spin Part is unfalsifiable interpretation."

Response. It registers its own two exposures, which is what distinguishes a reading from a slogan. The forbidden outcome: a convention-independent partition of the $\frac{1}{2}$ — if the community ever produces a scheme-independent decomposition that all experiments agree on, the custody reading dies, whereas the standard picture merely lacks one. And the debt: D-P6-3 requires the fiber computation to return $j = \frac{1}{2}$ or the reading dies arithmetically (§32). An interpretation that names the observation that would kill it, and the computation that could kill it, is falsifiable in the only sense that matters.

Objection 11 (O-P6-8) (the Kaluza–Klein technician)
"Why should the zero-mode floor sit at the minimal winding? Your lock needs that and does not prove it."

Response. Correct, and declared: the floor is the GDOS tower's lowest level (T-GDOS-9.1, consumed at its home paper's grade), the chirality-protection mechanism is exhibited in Appendix G, and the explicit warped profiles are owed as D-P6-5. The dependence is written into T-P6-2's own statement rather than buried. A reader who rejects the tower theorem rejects the lock with it — and the ledger says so in exactly those words. That is the intended behavior of the honesty apparatus, not a concession extracted by the objection.

Objection 12 (O-P6-11) (the neutron-lifetime specialist)
"The bottle–beam lifetime discrepancy already strains your Part VIII."

Response. It strains nothing here: both mundane resolutions (a systematic in either method) live entirely within the standard electroweak computation this paper quotes rather than derives, and the exotic resolutions are pre-sorted by the winding constraint (§76) into the survivable (invisible channels conserving the winding) and the fatal (dark decays violating it). The framework is one of the few onlookers to have stated, in advance and in print, which resolution would kill it and which would not. A four-sigma tension whose resolutions are pre-sorted is an asset to a falsifiable framework, not a threat.

J The frame, the record, and the birth

Objection 13 (O-P6-12) (the referee, on packaging)
"Eleven questions is packaging; several are the same question."

Response. Guilty, by design, and the charge is the thesis: the paper's claim from the Preface onward has been that the eleven are faces of one fact. The count is the map; the fact — one basin, one winding, one door — is the territory. The packaging dissolves exactly where the physics says it should, and nowhere else: Q4 and Q5 merge (one mechanism, two faces), Q6 and Q7 merge (one fact, observational and structural), and no one has accused Q3 and Q10 of being the same question, because they meet only at the geometry.

Objection 14 (O-P6-14) (the journal referee, on the record)
"A historical Part in a physics paper is special pleading. Part VII reads as a priority claim dressed as scholarship."

Response. Three fences answer this, and they are built into the Part itself. First, Part VII derives nothing: its own status ledger (§71) records that no claim of the paper is graded on anything said there, and a reader who skips it loses no equation. Second, its registers never mix: the external history is cited to the printed literature, checkable by anyone with library access, and the framework's own chronology is marked as dated testimony — offered as record of when commitments were made, explicitly not as evidence that they are true. Third, the history cuts against the paper as much as for it: the record shows the field declining the axiom three times for reasons the Part calls *correct*, and it reports the brane-world convergence that a priority claim would have omitted. A record with those three properties is the opposite of special pleading; it is the paper showing its provenance the same way it shows its arithmetic.

Objection 15 (O-P6-15) (the equivalence-principle experimentalist)
"A Stueckelberg-massive $\mathrm{U}(1)_B$ predicts no fifth force at any accessible range — so my nulls can never confirm you, only kill you. Calling the null a 'standing confirmation' is rhetoric."

Response. The asymmetry is real and the response concedes it cheerfully: F-P6-5 is a falsifier, not a smoking gun, and the paper's language — the null "testifies for" the structure — means exactly what a null can mean: every year the torsion balances run without a composition-dependent signal, the massless and light-mediator alternatives that would falsify the Stueckelberg structure are excluded more deeply. What makes the relationship more than rhetoric is the history: the test bodies at the frontier were chosen to maximize the baryonic difference (§66), so the equivalence-principle program is, operationally, a dedicated search for the one force this framework forbids. A theory should be so lucky twice: its sharpest kill criteria (F-P6-1, F-P6-5) are both experiments that grow stronger every year they stay silent — and both communities existed before the theory did.

Objection 16 (O-P6-16) (the baryogenesis cosmologist)
"TeV-scale resonant leptogenesis is one mechanism among many. Importing it as 'the' origin of matter overstates a model choice."

Response. The import is graded, and the grading is the answer. What this paper proves at its own grade is the *structural selection* (§83): in this geometry, $\Delta B = \pm 1$ minting does not exist, so whatever made the baryons had to make them through the $3\mathbb{Z}$ door from a lepton-sector asymmetry — leptogenesis is *forced as a class*, not chosen from a menu. The specific TeV-scale resonant chain is then imported from the CPT companion at its declared conditional grade, named input and named conjecture intact (§84), and the paper's consistency sentence — the door open exactly when needed, sealed exactly after — holds for the class, not only the instance. If the companion's chain dies, the class survives; if the class dies — if baryogenesis is ever shown to require $\Delta B = \pm 1$ minting — then F-P6-1's silence and Q10 become mutually inconsistent, and the framework dies with the contradiction. That exposure is registered, which is what "the" origin story costs in this cohort.

Objection 17 (O-P6-17) (the lattice practitioner, on the mass)
"You did not derive the proton mass; the lattice did. Your πe is one number; everything downstream — the running, the thresholds, the 2.76 — is standard machinery and lattice output. Calling 897 MeV a prediction is marketing."

Response. The division of labor is stated in the Part itself, in exactly your terms (§21.4): the framework supplies the *input*; the renormalization group supplies the transport (standard); the lattice supplies the pure number (yours, with gratitude, at (14)). What is claimed is precisely and only the piece the standard account does not have: the input's *value*, as a closed form, at a published grade with its selection audit in the open (§21.2 — including the look-elsewhere factor, which most "derivations" of constants never print). Grant that one input and the 897 MeV follows with no further freedom anywhere; decline it and you are back to the world average and the standard account, which is the correct null. Two further points are yours to hold the paper to. First, the last import — the 2.76 — is the subject of a registered program with a printed kill window (§24.1); if the wall computation lands outside $[1.42, 1.93]$, that program dies in public. Second, the claim's standard is yours as well: the registration is falsifiable at the coupling ($\alpha_s^{-1}(M_Z) = \pi e$ at first order, against a world average whose precision improves yearly), and GG-A9-SM carries that exposure explicitly. A marketing claim is one that cannot lose; this one can.

The objections above are the seventeen the paper judges strongest; the tradition that produced them remains open. A reader holding an objection not listed here is invited to lodge it against the claim-status ledger (Table 28): every claim in this paper carries its grade, its fences, and its home, so the target is never ambiguous.

Acknowledgments

This work was developed through extensive iterative collaboration with three large language models: ChatGPT (OpenAI) for exploratory drafting, narrative development, and broad-scope ideation; Perplexity for literature synthesis, citation verification, and recent experimental cross-referencing; and Claude (Anthropic) for structural organization, mathematical consistency checking, LaTeX typesetting, and final manuscript preparation. The sequential refinement of the GG-Theory framework (GG-Constitution / GG-6 / BI-6 / GDOS / Gi-4 Pillars / Qi-4 Pillars) across hundreds of conversation sessions with these three systems was essential to the coherence of the present paper. The author thanks Aaron Blaisdell and Hirotaka Iwasaki for stimulating discussions on the program's interdisciplinary scope and for critical feedback on the accessibility of the presentation. The author also thanks hundreds of collaborators in the Elegant Mind Club over the past decade, including Javier Carmona, Elizabeth Milles, Mingda He, Syed Bashir Hydari, Brian Ta, Chris Dao, Umaima Afifa, Isabella Bestanoby, Caominh Le, and Natsuko Yamaguchi.

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 XVI
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 theorem, table, or section each one underwrites. The notes are written for two readers at once. For the newcomer, they trace the lineage of the proton's story: from Rutherford's naming through the quark model, QCD, the unification sentence of 1974, and the seventy-year road of gauged baryon number that Part VII records, to the cohort papers whose stability theorem this paper completes. 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 the cohort's two-part style: **Section A** lists the sister papers of the GG-Theory cohort cited in this paper, in the canonical order of the program; **Section B** lists the external literature, in order of first appearance in the paper. Each entry closes with the location of its first citation; the list contains no entry that is not cited in the text. All cohort preprints are available at https://preprints.arisaka-gg.org/.

A. Papers by Katsushi Arisaka (the GG-Theory cohort)

Arisaka, K. (2026). 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. Arisaka-GG-A1-Constitution.
Preprint, available at https://preprints.arisaka-gg.org/a1-constitution/.
Relevance. The constitutional root: the axioms (locality–causality, single variational principle, minimal structure) under which every "derived" in this paper is derived, and the constitutional locality of $\mathrm{U}(1)_B$ from which Q7 begins. First cited in §11.

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, available at https://preprints.arisaka-gg.org/a2-gg6/.
Relevance. The realization of the constitution as six-dimensional geometry: the bulk $M_4 \times I_r \times S^1_\theta$ whose boundary this paper's proton inhabits, and the geometry–gauge locking behind the descent (4). First cited in §11.

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, available at https://preprints.arisaka-gg.org/a3-bi6/.
Relevance. The Green–Schwarz inflow that absorbs the two non-vanishing coefficients of Part VI's anomaly ledger — hypothesis H3 of the stability theorem, consumed here verbatim. First cited in §11.

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://preprints.arisaka-gg.org/a4-euclid/.
Relevance. The lineage paper, and the one that sizes this paper's claim from outside it: each step of the geometrization of physics turned a quantity that had been a law into a property of a space, and the proton's exact charge and sharp mass becoming properties of a basin is one more step in that sequence rather than a break with it. It is also where the step is measured against the ones before it. First cited in §6.1.

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://preprints.arisaka-gg.org/a5-gdos/.
Relevance. The open-system projection and the tower theorem (T-GDOS-9.1) whose zero-mode floor Part VI reads the baryonic winding from; also the home of the parity assignment (6), whose conjugation action Part VI reads from the realization paper's deployed canon. First cited in §11.

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, available at https://preprints.arisaka-gg.org/a6-grip/.
Relevance. The home of this paper's conceptual spine: the GRIP runtime, the GA/GGA distinction, and GRIP-In/GRIP-Out of §§8–10. The attractor machinery: GGA ground states, the GFF functional whose unique deepest basin Part III's theorem concerns, GSSB branch selection (Part V's confinement reading), and GRIP-In descent pricing (Part VIII's neutron). First cited in §11.

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, available at https://preprints.arisaka-gg.org/a7-qi4/.
Relevance. The home of the Arisaka equation (8) and the information charge $\mathrm{U}(1)_{Qi}$: Part XI consumes the current locking and the constant $\mathsf{Q_B}$ at this paper's declared candidate grade, and quotes its kill criterion as F-P6-6. First cited in §2.

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://preprints.arisaka-gg.org/a8-qm/.
Relevance. The source of the readout language this paper speaks in. "Readout", "label" and "register" are that paper's terms with that paper's content, and Part IV's central distinction — between a representation label of the boundary readout and a bulk ledger of shares — has no

force unless its account of what a readout is holds. Where this paper says a quantity is read rather than possessed, the warrant is there. First cited in §6.1.

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, available at https://preprints.arisaka-gg.org/a9-sm/.
Relevance. The largest inheritance: the bulk group, the descent, the matter packets and B-assignments, the stability theorem T-SM-60.1 whose hypothesis H2 this paper discharges, the derived couplings and transmutation pricing of the mass, and the basin/gate architecture. Part VI is this paper's repayment of A9's explicit deferral. First cited in §12; consumed throughout.

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, available at https://preprints.arisaka-gg.org/a10-cosmos/.
Relevance. The cosmological consumer of the birth chain: GG-P5-CPT's η_B is delivered there, and Part X's consistency sentence connects this paper's anomaly door to that delivery. First cited in §14.

Arisaka, K. (2026). The Geometric Inevitability of Cosmos, Life, and Mind: The Self-Referential Closure of the GG-Theory Program. Arisaka-GG-A11-Origin.
Preprint, available at https://preprints.arisaka-gg.org/a11-origin/. No result of the present paper depends on it.
Relevance. The capstone that proves the Chain of GRIP-Out (§9): the determined cascade $\mathcal{C} \to \mathsf{GGA}_1 \to \cdots \to \mathsf{GGA}_{18}$ in which each stable object, the proton included, is the Ground Geometric Attractor of its stratum, and T-GGA-as-Ground-State that fixes the universality of every readout. This paper's proton is the baryonic rung of that chain; GG-A11-Origin is where the upward story — atoms, molecules, life, mind — is carried at its stated grade. First cited in §9.

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, available at https://preprints.arisaka-gg.org/p1-kk/.
Relevance. The collider falsifier of the same compact direction this paper reads. P1 reads that direction's lock scale and P6 reads its winding, and both readings require it to be non-spatial: a spatial circle carries a tower of states and a modulus, and neither paper survives one. The two are exposed to different experiments and to the same geometry. First cited in §6.1.

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, available at https://preprints.arisaka-gg.org/p2-n3/.
Relevance. The two-sided family theorem ($N \geq 3$ from the CP-phase lower bound, $N \leq 3$ from the capacity theorem T-N3-6: π of budget per family against triangle-number tolls, exactly saturated at $N = 3$, conditional on the coupling clause and the integrality lemma L-INT) that Part IX doubles into the six flavors of Q9; the grammar of "derived (conditional)" fencing this paper follows is also this sister paper's. First cited in §13; consumed in Part IX.

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, available at https://preprints.arisaka-gg.org/p3-electron/.
Relevance. The sister paper and the method: questions stated sharply, the honest status table, ground-state uniqueness read as many faces, fences and debts named, kills pre-registered. Its positron — the conjugate readout of the same basin — is the worked example Part VI generalizes to the antibaryon as the reversed winding. First cited in the Preface.

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, available at https://preprints.arisaka-gg.org/p4-real/.
Relevance. The Foundations Branch member that derives the origin of the i the whole quantum apparatus runs on: the gauge phase from the compact circle's quarter-turn, the state-space i from the causal clock. Recorded here at roster level, in the cohort overview of §6.1, and not used as a premise anywhere in this paper — but the compact direction whose quarter-turn supplies that phase is the same direction whose winding Part VI reads as baryon number, so a reader auditing where that circle came from should go there rather than here. First cited in §6.1.

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, available at https://preprints.arisaka-gg.org/p5-cpt/.
Relevance. Two inheritances at two grades: at theorem grade, the origin of antiparticles (T-P5-A/B/C/C2) — whose reversal-is-conjugation identity is the closure condition of Part VI's dihedral structure, the deepest contact between the two papers; at conditional grade, the TeV-scale leptogenesis chain that Part X imports with its named input and named conjecture intact. First cited in §14; consumed in Parts VI and X.

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, available at https://preprints.arisaka-gg.org/w1-symmetry/.
Relevance. The cohort's symmetry review, whose ladder ends at *protection without symmetry* — the register in which this paper's central claim is best stated. A symmetry-based proton-stability argument can be broken, and historically was; an integer winding cannot. §10 names the proton as that ladder's sharpest instance. First cited in §10.

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, available at https://preprints.arisaka-gg.org/w2-holonomy/.
Relevance. The treatise on the fork this paper's protection argument rests on — holonomy requires closed loops, and an interval has none — and the source of the tier distinction §10 draws between a winding class, which is frozen, and a continuous circle modulus such as the Higgs, which is merely finite. First cited in §10.

Arisaka, K. (2026). The Kaxion: Cold Dark Matter as the Non-Spatial Compact-Angle Pseudoscalar of GG-6. Arisaka-GG-C1-Kaxion.
Preprint, available at https://preprints.arisaka-gg.org/c1-kaxion/.
Relevance. The cohort's other physical exploitation of the phase circle's topology. This paper reads a winding of that circle as baryon number; the Kaxion reads an angle on the same circle as dark matter, with a derived mass and a laboratory window. The two readings are held by one ledger, so a result that moved the ledger would move both. First cited in §6.1.

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, available at https://preprints.arisaka-gg.org/c2-hubble/.
Relevance. The derived expansion history in which the baryon inventory of Part X has to land. This paper makes protons and counts them against a cosmological number; that number is read off the same inventory the corridor analysis works in, so a shift there moves this paper's target and not merely its background. First cited in §6.1.

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, available at https://preprints.arisaka-gg.org/c3-bh/.
Relevance. The owner of the question this paper does not ask. Baryon number here is a global topological datum that no local operation can change, and the one place in the cohort where the fate of a global datum at a horizon is worked out is the horizon-as-port reading. This paper's stability theorem is stated for the accessible-energy regime and says nothing about that case; C3 is where a reader should go, and the two accounts have not been reconciled. First cited in §6.1.

B. Other references

E. Rutherford. Collision of α particles with light atoms. IV. An anomalous effect in nitrogen. *Philosophical Magazine* **37**, 581 (1919).
Relevance. The proton enters physics: hydrogen nuclei knocked from nitrogen identify the first constituent of all nuclei. The century of §1 opens here. First cited in §1.

J. Chadwick. Possible existence of a neutron. *Nature* **129**, 312 (1932).
Relevance. The twin arrives: the neutron's discovery poses Q8 in its first form — a particle a tenth of a percent heavier that dies free and lives bound. First cited in §1.

R. Frisch and O. Stern. Über die magnetische Ablenkung von Wasserstoffmolekülen und das magnetische Moment des Protons. *Zeitschrift für Physik* **85**, 4 (1933).
Relevance. The first crack in pointlikeness: $\mu_p \approx 2.79\,\mu_N$ against the Dirac expectation of 1 — the proton caught having an inside fifteen years early. First cited in §1.

R. Hofstadter. Electron scattering and nuclear structure. *Reviews of Modern Physics* **28**, 214 (1956).
Relevance. The inside acquires a shape: form factors map the charge cloud near 0.8 fm, turning "structure" from inference to geometry. First cited in §1.

M. Gell-Mann. A schematic model of baryons and mesons. *Physics Letters* **8**, 214 (1964).
Relevance. The quark model: the proton as *uud*, charge in thirds — and, from the first page, the puzzle of Q5: constituents never seen alone. First cited in §1.

G. Zweig. An SU(3) model for strong interaction symmetry and its breaking. CERN Reports 8182/TH.401 and 8419/TH.412 (1964).
Relevance. The independent invention of the constituent picture ("aces"); cited with Gell-Mann as the birth of Q4/Q5's modern form. First cited in §1.

M. Breidenbach, J. I. Friedman, H. W. Kendall, et al. Observed behavior of highly inelastic electron–proton scattering. *Physical Review Letters* **23**, 935 (1969).
Relevance. The quarks are real: SLAC's deep inelastic scattering finds the hard centers inside the cloud Hofstadter mapped. First cited in §1.

D. J. Gross and F. Wilczek. Ultraviolet behavior of non-Abelian gauge theories. *Physical Review Letters* **30**, 1343 (1973).
Relevance. Asymptotic freedom: why the SLAC quarks scatter free while never escaping — half of Q4's modern statement. First cited in §1.

H. D. Politzer. Reliable perturbative results for strong interactions? *Physical Review Letters* **30**, 1346 (1973).
Relevance. The simultaneous discovery of asymptotic freedom; cited with Gross–Wilczek. First cited in §1.

H. Fritzsch, M. Gell-Mann, and H. Leutwyler. Advantages of the color octet gluon picture. *Physics Letters B* **47**, 365 (1973).
Relevance. QCD as the theory of the strong force — the Lagrangian whose central qualitative fact (Q4) remains, at Clay grade, unproven from it. First cited in §1.

H. Georgi and S. L. Glashow. Unity of all elementary-particle forces. *Physical Review Letters* **32**, 438 (1974).
Relevance. The death sentence: minimal SU(5) unification, whose X, Y bosons demand proton decay — the prediction Kamiokande was built to test and the proton declined to honor. The structural contrast for Part VI: there the X, Y live on the boundary; here they are bulk-only. First cited in §1.

K. G. Wilson. Confinement of quarks. *Physical Review D* **10**, 2445 (1974).
Relevance. The lattice: confinement made computable — numerically established ever since, analytically open still, which is exactly the register Part V engages it at. First cited in §1.

K. Arisaka, et al. (Kamiokande Collaboration). Search for nucleon decay into charged lepton + mesons. *Journal of the Physical Society of Japan* **54**, 3213 (1985).

Relevance. Kamiokande's nucleon-decay search — the experiment this paper's sixth question was built, literally, to answer, by the author, 1979–1985. The null result reported here is the first hardening of the silence that Part VI derives as a theorem. First cited in the Preface.

K. Hirata, et al. (Kamiokande-II Collaboration). Observation of a neutrino burst from the supernova SN1987A. *Physical Review Letters* **58**, 1490 (1987).

Relevance. What the tank saw instead: the neutrino burst that founded neutrino astronomy — the great improvised success of the instrument built for Q6. First cited in §1.

J. Ashman, et al. (European Muon Collaboration). A measurement of the spin asymmetry and determination of the structure function g_1 in deep inelastic muon–proton scattering. *Physics Letters B* **206**, 364 (1988).

Relevance. The spin crisis: the quark spins carry a small fraction of the proton's spin — Q3's birth certificate, and Part IV's opening exhibit. First cited in §1.

A. D. Sakharov. Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe. *JETP Letters* **5**, 24 (1967).

Relevance. The three conditions any answer to Q10 must satisfy; the standard account's honest foundation stone in Table 1. First cited in §3.

M. Fukugita and T. Yanagida. Baryogenesis without grand unification. *Physics Letters B* **174**, 45 (1986).

Relevance. Leptogenesis: the mechanism family GG-P5-CPT's chain instantiates in the resonant TeV-scale regime; Part X imports that chain at its declared grade. First cited in §3.

G. 't Hooft. Symmetry breaking through Bell–Jackiw anomalies. *Physical Review Letters* **37**, 8 (1976).

Relevance. The anomaly vertex: baryon-number violation as a topological effect, not a local operator — precisely the character of the single $\Delta B \in 3\mathbb{Z}$ door in Part VI's ledger, closed cold, open hot. First cited in §14.

S. Dürr, et al. Ab initio determination of light hadron masses. *Science* **322**, 1224 (2008).

Relevance. The lattice weighs the proton from first principles: the mass is interaction energy to the percent — the empirical anchor of Q1's "ninety-nine percent" and of Part III's transmutation pricing. First cited in §1.

R. Pohl, et al. The size of the proton. *Nature* **466**, 213 (2010).

Relevance. The muonic-hydrogen radius that opened the decade of the proton-radius puzzle — cited as part of the precision era's texture; engaged, at objection level, in Part XII. First cited in §1.

A. Takenaka, et al. (Super-Kamiokande Collaboration). Search for proton decay via $p \to e^+\pi^0$ and $p \to \mu^+\pi^0$ with an enlarged fiducial volume in Super-Kamiokande I–IV. *Physical Review D* **102**, 112011 (2020).

Relevance. The number Q6 stands on: $\tau/B(p \to e^+\pi^0) > 2.4 \times 10^{34}$ yr at 90% CL — the silence, quantified. First cited in §1.

Super-Kamiokande Collaboration. Search for proton decay via $p \to e^+\pi^0$ and $p \to \mu^+\pi^0$ with a 0.37 Mton-year exposure of Super-Kamiokande. *Physical Review D* **110**, 112011 (2024).
Relevance. The deepest exposure to date — 0.37 megaton-years of watched protons; the current edge of the four-decade silence, and the baseline the 2040-class searches extend. First cited in §1.

M. J. Borchert, et al. (BASE Collaboration). A 16-parts-per-trillion measurement of the antiproton-to-proton charge–mass ratio. *Nature* **601**, 53 (2022).
Relevance. The mirror held to the proton at record precision: the conjugate-readout reading of the antiproton (Part VI, with GG-P5-CPT) is tested here — falsifier F-P6-4's current anchor. First cited in §1.

F. M. Gonzalez, et al. (UCNτ Collaboration). Improved neutron lifetime measurement with UCNτ. *Physical Review Letters* **127**, 162501 (2021).
Relevance. The bottle: 877.75 ± 0.28 s — one side of the four-sigma lifetime discrepancy Part VIII reports at face value and claims nothing about. First cited in §1.

A. T. Yue, et al. Improved determination of the neutron lifetime. *Physical Review Letters* **111**, 222501 (2013).
Relevance. The beam: 887.7 ± 2.2 s — the other side of the discrepancy; together with the bottle value, the open experimental item of Q8's precision era. First cited in §1.

S. Navas, et al. (Particle Data Group). Review of particle physics. *Physical Review D* **110**, 030001 (2024).
Relevance. The ledger of record for every measured value this paper quotes — the proton's mass and moment, the neutrality of matter, the quark-search nulls, the lifetime tables; the empirical anchor table of Part XIV references it throughout. First cited in §2.

A. Accardi, et al. Electron–Ion Collider: the next QCD frontier. *European Physical Journal A* **52**, 268 (2016).
Relevance. The instrument of the pre-registered face of Q3: where the spin decomposition sharpens while — this paper predicts — the readout label does not move. First cited in §1.

G. Bressi, G. Carugno, F. Della Valle, G. Galeazzi, G. Ruoso, and G. Sartori. Testing the neutrality of matter by acoustic means in a spherical resonator. *Physical Review A* **83**, 052101 (2011).
Relevance. The neutrality of bulk matter at the $10^{-21}\,e$ level — the experimental face of the one-codebook identity (24): hydrogen is neutral by algebra, and this is the algebra's precision audit. First cited in §25.

M. Ahmadi, et al. (ALPHA Collaboration). An improved limit on the charge of antihydrogen. *Nature Communications* **7**, 12308 (2016).

Relevance. The conjugate readout audited: antihydrogen's charge bounded at 0.71 parts per billion — the winding rigidity of §25.2 holding on the reversed orientation, part of falsifier F-P6-4's family. First cited in §25.

R. L. Jaffe and A. Manohar. The g_1 problem: deep inelastic electron scattering and the spin of the proton. *Nuclear Physics B* **337**, 509 (1990).
Relevance. The partonic spin ledger (27) — the canonical statement of what the polarized-scattering program measures, and one of the two conventions whose mutual irreducibility is Part IV's central datum. First cited in §30.

X. Ji. Gauge-invariant decomposition of nucleon spin. *Physical Review Letters* **78**, 610 (1997).
Relevance. The gauge-invariant spin ledger (28) and its sum rule through generalized parton distributions — the second convention, whose principled disagreement with the first about orbital attribution is exactly the scheme-dependence Part IV reads as bulk bookkeeping. First cited in §30.

D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang. Evidence for polarization of gluons in the proton. *Physical Review Letters* **113**, 012001 (2014).
Relevance. The RHIC-era determination that the gluon polarization is real and positive over the measured range — closing the all-gluon rescue of the spin crisis and setting the ΔG used in the ledger arithmetic of Appendix B. First cited in §29.

G. S. Bali. QCD forces and heavy quark bound states. *Physics Reports* **343**, 1 (2001).
Relevance. The review of record for the static potential (30) and the string tension — the measured shape of the cage that Part V's sixteen-tonne arithmetic and Appendix C stand on. First cited in §34.

A. Bazavov, et al. (HotQCD Collaboration). Chiral crossover in QCD at zero and non-zero chemical potentials. *Physics Letters B* **795**, 15 (2019).
Relevance. The lattice determination $T_c = 156.5 \pm 1.5$ MeV of the deconfinement crossover — the temperature above which Part V's custody split (bulk color mobility, integer boundary readout) takes over from the confined phase, and the QGP stress-test of C-P6-1 begins. First cited in §35.

Y. Hosotani. Dynamical mass generation by compact extra dimensions. *Physics Letters B* **126**, 309 (1983).
Relevance. The mechanism by which a Wilson line on a compact cycle breaks gauge symmetry dynamically — the machinery whose hypercharge direction carries both GG-A9-SM's Higgs and, at the center point $W(2) = z$, this paper's $\mathbb{Z}_3$-lock. First cited in §56.

Y. Kawamura. Triplet–doublet splitting, proton stability and an extra dimension. *Progress of Theoretical Physics* **105**, 999 (2001).
Relevance. The orbifold-GUT refinement of the descent — boundary conditions doing the work of the GUT Higgs sector — whose doublet–triplet and proton-stability instincts Part VI's lock inherits, sharpens to the unique $\mathbb{Z}_3$ point, and converts from parity choices into the winding that writes baryon number. First cited in §56.

M. B. Green and J. H. Schwarz. Anomaly cancellations in supersymmetric $D = 10$ gauge theory and superstring theory. *Physics Letters B* **149**, 117 (1984).
Relevance. The inflow mechanism by which a higher-dimensional structure absorbs an anomaly the four-dimensional spectrum cannot cancel alone — the external ancestor of the BI-6 bookkeeping (GG-A3-BI6) that hypothesis H3 consumes for the two non-vanishing entries of the ledger of §58. First cited in §58.

E. C. G. Stückelberg. Die Wechselwirkungskräfte in der Elektrodynamik und in der Feldtheorie der Kernkräfte. *Helvetica Physica Acta* **11**, 225 (1938).
Relevance. The 1938 construction by which a U(1) gauge boson acquires mass while the rigid symmetry survives exactly — the reason this framework can have gauged baryon number, no baryonic fifth force, and an exact selection rule all at once. An eighty-eight-year-old trick, load-bearing in a 2026 theorem. First cited in §58.

M. Baldo-Ceolin, et al. A new experimental limit on neutron–antineutron oscillations. *Zeitschrift für Physik C* **63**, 409 (1994).
Relevance. The free-neutron oscillation bound ($\tau_{n\bar{n}} > 0.86 \times 10^8$ s, ILL) — the $\Delta B = 2$ face of the winding selection rule, forbidden here as absolutely as decay itself; falsifier F-P6-3's anchor, with bound-neutron searches and the ESS proposal extending it. First cited in §60.

S. Borsanyi, et al. (Budapest–Marseille–Wuppertal Collaboration). Ab initio calculation of the neutron–proton mass difference. *Science* **347**, 1452 (2015).
Relevance. The lattice QCD+QED decomposition of the hair's-breadth splitting — quark-mass part +2.52 MeV, electromagnetic part −1.00 MeV — the first-principles form of Part VIII's competition (51), against which the framework's toll ledger is checked. First cited in §24.

V. E. Barnes, et al. Observation of a hyperon with strangeness minus three. *Physical Review Letters* **12**, 204 (1964).
Relevance. The Ω^-: predicted with its mass by symmetry, found on cue — the discovery that made quarks undeniable, and, in Part IX's tower, the specimen proving that *labels* (three units of strangeness) can buy thirteen orders of magnitude of lifetime. First cited in §79.

N. Aghanim, et al. (Planck Collaboration). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics* **641**, A6 (2020).
Relevance. The precision inventory behind (55): the baryon density whose part-per-billion smallness — and stubborn non-zeroness — is Q10 stated as a measurement. First cited in §82.

V. A. Kuzmin, V. A. Rubakov, and M. E. Shaposhnikov. On anomalous electroweak baryon-number non-conservation in the early universe. *Physics Letters B* **155**, 36 (1985).
Relevance. The realization that the electroweak anomaly's transitions are unsuppressed at high temperature — the door of Parts VI and X in its original form, and the reason a lepton asymmetry can become the baryons of (55). First cited in §64.

J. A. Harvey and M. S. Turner. Cosmological baryon and lepton number in the presence of electroweak fermion-number violation. *Physical Review D* **42**, 3344 (1990).

Relevance. The chemical-potential bookkeeping behind the door's exchange rate (56) — the 28/79 walked in Appendix F. First cited in §84.

A. Pilaftsis and T. E. J. Underwood. Resonant leptogenesis. *Nuclear Physics B* **692**, 303 (2004).
Relevance. The quasi-degenerate regime in which TeV-scale leptogenesis attains the required asymmetry — the external home of the resonance physics whose condition is the GG-P5-CPT chain's one named input. First cited in §84.

E. W. Kolb and M. S. Turner. *The Early Universe.* Addison–Wesley, Redwood City (1990).
Relevance. The standard freeze-out arithmetic behind the annihilation catastrophe — the 10^{-18} of Appendix F that makes a pre-annihilation asymmetry non-optional. First cited in §82.

T. D. Lee and C. N. Yang. Conservation of heavy particles and generalized gauge transformations. *Physical Review* **98**, 1501 (1955).
Relevance. The founding Letter: gauge baryon number in analogy with electromagnetism — the founder's axiom of §52, proposed seventy years early, and wounded in its own single page by the Eötvös-data bound on a massless baryonic photon. Part VII is the record of what happened to it. First cited in §52.

A. Pais. Remark on baryon conservation. *Physical Review D* **8**, 1844 (1973).
Relevance. The first massive-boson evasion of the Eötvös wound — gauge B, give the boson a Higgs mass, lose the long-range force — the direct ancestor of the Stueckelberg logic Part VI runs on, published as a three-page "Remark" that gathered no school. First cited in §65.

E. Fischbach, D. Sudarsky, A. Szafer, C. Talmadge, and S. H. Aronson. Reanalysis of the Eötvös experiment. *Physical Review Letters* **56**, 3 (1986).
Relevance. The "fifth force" episode: the one wrong revival of a baryon-coupled force, dead within four years — whose permanent legacy, the purpose-built equivalence-principle search machine, is the experimental community that falsifier F-P6-5 inherits. First cited in §66.

R. Foot, G. C. Joshi, and H. Lew. Gauged baryon and lepton numbers. *Physical Review D* **40**, 2487 (1989).
Relevance. The anomaly price named in the open: with the known generations, gauged B demands new exotic fermions ("anomalons") — the four-dimensional bill that this framework pays instead at six dimensions, through the BI-6 inflow, with the spectrum untouched. First cited in §67.

C. D. Carone and H. Murayama. Possible light U(1) gauge boson coupled to baryon number. *Physical Review Letters* **74**, 3122 (1995); see also *Physical Review D* **52**, 484 (1995).
Relevance. The leptophobic window: a gauged-B boson lighter than the Z still experimentally alive in 1995 — the minority line's measure of how little the field had looked for the force it had declined to gauge. First cited in §67.

P. Fileviez Pérez and M. B. Wise. Baryon and lepton number as local gauge symmetries. *Physical Review D* **82**, 011901(R) (2010); erratum **82**, 079901 (2010).

Relevance. The modern revival, fifty-five years after the Letter: anomalies canceled by an extra generation, dark-matter stability as the advertised bonus — gauged B still entering as an extension seeking a home, which is the minority line's signature to the present day. First cited in §67.

T. A. Wagner, S. Schlamminger, J. H. Gundlach, and E. G. Adelberger. Torsion-balance tests of the weak equivalence principle. *Classical and Quantum Gravity* **29**, 184002 (2012).
Relevance. The modern benchmark of the experiment Lee and Yang first invoked: beryllium against titanium, chosen to maximize the difference in baryon number per unit mass, $\eta = (0.3 \pm 1.8) \times 10^{-13}$ — the standing null a Stueckelberg-massive $\mathrm{U}(1)_B$ demands, and falsifier F-P6-5's anchor. First cited in §66.

L. E. Ibáñez, F. Marchesano, and R. Rabadán. Getting just the standard model at intersecting branes. *Journal of High Energy Physics* **11**, 002 (2001).
Relevance. The brane convergence: in intersecting-brane Standard Models baryon number is necessarily gauged, Green–Schwarz-massive, and proton-protecting in perturbation theory — independent corroboration of Part VI's mechanism at a different price (ten dimensions, supersymmetry, extended objects), recorded in §68 and weighed in §94. First cited in §68.

S. Mandelstam. Vortices and quark confinement in non-Abelian gauge theories. *Physics Reports* **23**, 245 (1976).
Relevance. The dual-superconductor picture of confinement — a chromomagnetic condensate squeezing electric flux into tubes — the mechanism family whose geometrization Part V's wall-and-winding account belongs to; compared honestly in Table 8. First cited in §38.

G. 't Hooft. On the phase transition towards permanent quark confinement. *Nuclear Physics B* **138**, 1 (1978).
Relevance. Center vortices: confinement as percolating $\mathbb{Z}_3$ flux — the standard account's sharpest center-based mechanism, and the lattice's best-supported one; the center bridge of §39 proposes the ancestry of exactly this $\mathbb{Z}_3$. Distinct from the 1976 anomaly paper cited as 't Hooft, 1976. First cited in §38.

M. Lüscher, K. Symanzik, and P. Weisz. Anomalies of the free loop wave equation in the WKB approximation. *Nuclear Physics B* **173**, 365 (1980).
Relevance. The universal $-\pi/12\,\hbar c/r$ correction to the confining potential — the vibrating string's Casimir energy, whose coefficient counts the tube's massless transverse modes and thereby powers the Goldstone-counting test of §42. First cited in §35.

N. Seiberg and E. Witten. Electric–magnetic duality, monopole condensation, and confinement in $\mathcal{N} = 2$ supersymmetric Yang–Mills theory. *Nuclear Physics B* **426**, 19 (1994).
Relevance. The only four-dimensional gauge theory in which confinement and the gap are theorems — proved by monopole condensation in the softly-broken $\mathcal{N} = 2$ theory — and the lesson Part V takes literally: provability arrives with rigidity. Here the rigid structure is the lock. First cited in §38.

J. Maldacena. The large-N limit of superconformal field theories and supergravity. *Advances in Theoretical and Mathematical Physics* **2**, 231 (1998).
Relevance. Gauge–gravity duality: in confining backgrounds the Wilson loop drapes along an infrared wall and the area law follows from geometry — the mechanism whose no-strings cognate is Part V's wall on the scale axis (§40), with the wall location priced rather than modeled. First cited in §38.

P. de Forcrand and M. D'Elia. On the relevance of center vortices to QCD. *Physical Review Letters* **82**, 4582 (1999).
Relevance. The sharpest lattice evidence in the mechanism debate: removing the center vortices from a configuration removes the string tension — and the chiral condensate with it. The center carries the cage; §39 proposes why. First cited in §38.

C. J. Morningstar and M. Peardon. The glueball spectrum from an anisotropic lattice study. *Physical Review D* **60**, 034509 (1999).
Relevance. The measured mass gap: the lightest pure-gauge glueball at 1.71 GeV $= 3.9\sqrt{\sigma}$ — the number the Clay problem asks mathematics to prove positive, quoted in Part V's preamble and Clay register so the reader always knows what Δ is physically. First cited in §34.

A. Jaffe and E. Witten. Quantum Yang–Mills theory. Clay Mathematics Institute Millennium Prize problem description (2000); in *The Millennium Prize Problems*, Clay Mathematics Institute / AMS (2006).
Relevance. The official problem: construct quantum Yang–Mills on $\mathbb{R}^4$ at Wightman-grade rigor and prove the mass gap. Part V's load-bearing preamble and the four-move register of §47 are calibrated against this text, including the paper's declination, in writing, of any claim on it. First cited in §34.

G. S. Bali, H. Neff, T. Düssel, T. Lippert, and K. Schilling (SESAM Collaboration). Observation of string breaking in QCD. *Physical Review D* **71**, 114513 (2005).
Relevance. The direct lattice observation of the string snapping at $r_b \approx 1.24$ fm — the budget $\sigma r_b \approx 1.22$ GeV paying for a light pair — the (B) face of the five-claim scorecard, and the reason physical confinement is (K) enforced through (L) plus (B) rather than an infinite potential. First cited in §35.

J. Greensite. *An Introduction to the Confinement Problem.* Lecture Notes in Physics **821**, Springer (2011).
Relevance. The monograph of record for the confinement problem — the center-symmetry criteria, the N-ality lore, the mechanism debate — and the recommended next book for the reader this Part is written for; the standard side of the center bridge is drawn from its account. First cited in §35.

X. Ji. QCD analysis of the mass structure of the nucleon. *Physical Review Letters* **74**, 1071 (1995).
Relevance. The founding document of the mass-budget literature: from two QCD inputs (the momentum sum rule and the trace anomaly), the four-term itemization of the proton's mass that §22.1 reviews and the thirty-year argument of §22.2 contests. First cited in §22.1.

Y.-B. Yang, J. Liang, Y.-J. Bi, Y. Chen, T. Draper, K.-F. Liu, Z. Liu. Proton mass decomposition from the QCD energy momentum tensor. *Physical Review Letters* **121**, 212001 (2018).
Relevance. The first complete lattice itemization of the proton's mass in the Ji ledger — quark energy 33(4)(4)%, glue 37(5)(4)%, condensates 9(2)(1)%, trace anomaly 23(1)(1)% ($\overline{\text{MS}}$, 2 GeV) — Table 4's source. First cited in §22.1.

C. Lorcé. On the hadron mass decomposition. *European Physical Journal C* **78**, 120 (2018).
Relevance. The two-term objection: a hadron's mass admits at most two consistently interpretable contributions; the quark-mass and trace-anomaly entries of four-term budgets are argued to be conventional, and pressure effects overlooked. One side of the live dispute §22.2 reviews. First cited in §22.2.

A. Metz, B. Pasquini, S. Rodini. Revisiting the proton mass decomposition. *Physical Review D* **102**, 114042 (2020).
Relevance. The renormalization-theory form of the two-term objection: the forward energy–momentum tensor has two independent form factors, and the individual sum-rule entries carry considerable scheme dependence at three loops; also the source for the heavy-quark sigma-term subtlety in §21.5. First cited in §21.5.

X. Ji. Proton mass decomposition: naturalness and interpretations. *Frontiers of Physics* **16**, 64601 (2021).
Relevance. The founding author's published rebuttal to the two-term critique: the rest-frame Hamiltonian budget defended as natural, and the quantum anomalous energy as measurable — the theory position behind the threshold-charm program. Cited so that §22.2 presents the dispute with both sides on the record. First cited in §22.2.

D. Bollweg, H.-T. Ding, X. Gao, S. Luo, S. Mukherjee. Lattice-QCD validation of hadron mass and trace-anomaly decomposition sum rules. arXiv:2601.13070 (2026), *Physical Review Letters*, in press at this writing.
Relevance. The milestone §22.3 turns on: all four rival mass sum rules computed for the same hadrons (charmonia) in one gradient-flow framework, with the anomalous/gluonic share ranging from ∼6% to ∼35% across ledgers — the itemization dispute, measured (Figure 11). First cited in §22.3.

A. Ali, et al. (GlueX Collaboration). First measurement of near-threshold J/ψ exclusive photoproduction off the proton. *Physical Review Letters* **123**, 072001 (2019).
Relevance. The opening measurement of the threshold-charm program: the exclusive cross section from threshold (8.2 GeV) to 11.8 GeV, falling less steeply than two-gluon-exchange models — the first measured caution about the simplest gluonic interpretation. First cited in §23.1.

S. Adhikari, et al. (GlueX Collaboration). Measurement of the J/ψ photoproduction cross section over the full near-threshold kinematic region. *Physical Review C* **108**, 025201 (2023).
Relevance. The full threshold dataset, and the collaboration's own register: the data are "inputs to theoretical models" of gluonic structure, with measured evidence for open-charm contributions

beyond gluon exchange — the model-mediation caution §23.1 carries into every anomaly-extraction claim. First cited in §23.1.

B. Duran, et al. Determining the gluonic gravitational form factors of the proton. *Nature* **615**, 813 (2023).
Relevance. The J/ψ-007 experiment: gluonic gravitational form factors extracted from threshold photoproduction, with a mass radius "notably smaller than the electric charge radius" across all models employed — the model-robust ordering registered in §23.3 as the first acceptance test of this paper's D-P6-5 profile debt. First cited in §23.2.

V. D. Burkert, L. Elouadrhiri, F. X. Girod. The pressure distribution inside the proton. *Nature* **557**, 396 (2018).
Relevance. The celebrated D-term "pressure" claim from deeply-virtual Compton scattering — cited here strictly as a pair with its published rebuttal (Kumerički, 2019), per the register of §23.2. First cited in §23.2.

K. Kumerički. Measurability of pressure inside the proton. *Nature* **570**, E1 (2019).
Relevance. The published reanalysis showing the same data consistent with zero quark pressure under a flexible parameterization — the reason §23.2 treats the 2018 pressure result as a claim, not a measurement, and the reason this paper registers no D-term claim of its own. First cited in §23.2.

D. C. Hackett, D. A. Pefkou, P. E. Shanahan. Gravitational form factors of the proton from lattice QCD. *Physical Review Letters* **132**, 251904 (2024).
Relevance. The lattice's flavor-separated gravitational form factors: quark and gluon momentum halves nearly equal ($A_q(0) = 0.510(25)$, $A_g(0) = 0.501(27)$), the gluon contribution extending the proton's radial size — the first-principles counterpart of the hall extractions in §23.2, and the comparison of record for any future D-P6-5 output. First cited in §23.2.

R. Abdul Khalek, et al. Science requirements and detector concepts for the Electron–Ion Collider: EIC Yellow Report. *Nuclear Physics A* **1026**, 122447 (2022).
Relevance. The community's flagship-machine statement of Q1: the origin of the nucleon's mass as a central EIC question, the trace anomaly as the target, threshold quarkonium as the route — the program within which §23.3 registers this framework's exposure. First cited in §23.3.

C. D. Roberts, D. G. Richards, T. Horn, L. Chang. Insights into the emergence of mass from studies of pion and kaon structure. *Progress in Particle and Nuclear Physics* **120**, 103883 (2021).
Relevance. The emergent-hadron-mass review: the hadronic GeV as the Standard Model's second, not-yet-understood mass mechanism, with the pion–proton dichotomy as its organizing puzzle — the community's own statement that OP-1 and OP-7 of §24 are open. First cited in §24.

R. Gupta, S. Park, M. Hoferichter, E. Mereghetti, B. Yoon, T. Bhattacharya. Pion–nucleon sigma term from lattice QCD. *Physical Review Letters* **127**, 242002 (2021).
Relevance. The demonstration that the same lattice ensembles yield $\sigma_{\pi N} = 41.9(4.9)$ or $59.6(7.4)$ MeV depending on the treatment of $N\pi$ excited states — two percent of the pro-

ton's mass riding on a systematics choice, the honest core of OP-6 and of §21.5's sigma discussion. First cited in §21.5.

A. Agadjanov, D. Djukanovic, G. von Hippel, H. B. Meyer, K. Ottnad, H. Wittig. Nucleon sigma terms with $N_f = 2 + 1$ flavors of $\mathcal{O}(a)$-improved Wilson fermions. *Physical Review Letters* **131**, 261902 (2023).
Relevance. The controlled lattice values this paper quotes for the proton's Higgs response: $\sigma_{\pi N} = 43.7(3.6)$ MeV, $\sigma_s = 28.6(9.3)$ MeV, with the dispersion-theory tension persisting at 2.4σ — the numbers behind the corrected mass-budget caption (Figure 10). First cited in §21.5.

M. R. Douglas. The Yang–Mills Millennium problem. *Nature Reviews Physics* **8**, 86 (2026).
Relevance. The current survey of record for the mass-gap problem: existence and gap both open, no clear path — the citation behind OP-4's status in §24, and the standard-side confirmation that Part V's Clay register placed the problem where it in fact stands. First cited in §24.