UCLA/Arisaka-GG-P3-Electron
v20.2 — August 22, 2026 — *Particle Branch*

The Electron as the Ground State of Nature

The Six Oldest Questions about the Electron, Closed and Fenced within GG-Theory

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Abstract

Every electron in the universe is exactly like every other: the same mass, the same charge, the same spin. No electron has ever been seen to decay, or to reveal an inner structure. Two heavier copies of it exist — and only two. Every electron has a mirror twin — the positron, of exactly equal mass and exactly opposite charge. And every electron somehow senses an electric field and falls toward the nearest proton. Since 1897, physics has treated these as six separate mysteries, answering some in fragments and others not at all.

This paper assembles, within Grand Geometric Theory, a single answer: the electron is the unique ground state of its sector of the boundary of a six-dimensional geometry. Identity and its measured values, absolute stability, the two excited copies that terminate at three, the absence of substructure at any scale, the response to fields, and the mirror twin are derived as six faces of that one fact — with every step that remains conjectural fenced by name, and the standard fragments credited where they are real. It is written as a review, for the reader beginning graduate study who noticed these questions and was told to move on.

After all, the most common particle of our existence deserves more than six separate accidents; it deserves to be the theorem the other facts were always pointing at.

Executive Summary

The question behind this paper is the oldest in particle physics, and the most personal one a physicist can ask of the matter in his own hands: what *is* an electron, that it should be what it is? Six specific questions have stood open since the electron's identification in 1897. **Q1** (identity): why is every electron exactly identical — and why *those* values of mass, charge, and spin? **Q2** (stability): why is the electron absolutely stable? **Q3** (copies): why do the muon and tau exist as heavier copies, and why are there exactly two? **Q4** (pointlikeness): why does the electron show no size and no substructure at any scale ever probed? **Q5** (sensing): why does an electron respond to an electric field at all? **Q6** (the twin): why does the electron have an antiparticle, and what is the positron?

Who this paper is for. This paper is written as a review article, for the first-year physics graduate student — the critical thinker who finished a degree carrying exactly these six naive, fundamental questions and was told, by silence or by syllabus, to move on. It is offered as a refresher: the questions are taken seriously, the standard answers priced exactly, and one geometric viewpoint developed far enough to show the six as one. It is simultaneously a gateway: every imported theorem is proved in the cohort papers it cites. The status tags below are the reading contract: nothing is asserted above its price.

The honest standard-physics ledger. This paper front-loads what standard physics genuinely answers, because its thesis survives only alongside that credit. Q1 has a real partial answer: in quantum field theory all electrons are excitations of one field, so exact likeness is automatic — but the field's mass, charge, and representation are free inputs: the answer explains sameness but none of its content. Q2 has a correct bookkeeping argument — lightest charged particle plus charge conservation — which presupposes exactly the unexplained spectrum termination that is Q3. Q5's sign rule (opposites attract) is a genuine theorem of QED, credited here without reservation. Q3 and Q4 have, in standard physics, no explanation of any kind; Q6's twin is explained only formally (QFT + the CPT theorem, credited) — what it *is* goes unaddressed.

The one fact. Within GG-Theory the six questions have one answer: *the electron is the unique Ground Geometric Attractor (GGA) — the ground state — of the charged-lepton stratum of the 4D boundary of the 6D bulk.*[1] Identity: every electron is the readout of the same unique ground basin (theorem within GDOS; GFF-ST7), with its values derived — $y_e = N/(L^3 2^{J+L+1})$ and $m_e^{\mathrm{QD}} = 0.511098$ MeV against the measured 0.510999 MeV (declared residual 1.9×10^{-4}); $\alpha^{-1} = 2^J + N^2 = 137$ QD-completed to 137.036; spin-$\frac{1}{2}$ from the quaternionic structure $\mathrm{Spin}(1,5) = \mathrm{SL}(2,\mathbb{H})$. Stability: the ground basin has no exit gate — there is nothing downhill, so the electron cannot decay (theorem within GDOS, importing GG-P2-N3's landscape). Copies: the muon and tau are the depth-1 and depth-0 basins of the same landscape — geometrically excited electrons — and

[1] Throughout the cohort, the 6D bulk is read on the field-theory side of the bulk–boundary correspondence: the fifth (scale) dimension is the renormalization-group axis $r = \ln(E_{\mathrm{GUT}}/\mu)$, not a Randall–Sundrum spatial dimension, and the scale profile denotes RG running; the explicit renormalization-group construction is given in Arisaka (2026, A2-GG6).

the ladder ends at three; this is GG-P2-N3's result, imported with its complete conditioning (two empirical inputs; the coupling clause with the integrality theorem L-INT, residue R-INT), never re-derived and never overclaimed. The twin: the positron is the conjugate readout of the same basin — the origin of antiparticles imported at theorem grade from GG-P5-CPT, the same-basin reading priced, its promotion registered (D-P3-4). Sensing: the force itself is derived — Newton's and Coulomb's laws descend in parallel from one bulk onto one equation of motion (AX-2): responding to a field is generalized free fall; the coupling's existence, quantization, and strength α are derived; the open-system arrows are priced as interpretive glosses; the sign rule's quantum reading remains QED's theorem, credited.

The new core: pointlikeness from non-spatial structure. Q4 is this paper's new derivational content. Under AX-2 a particle *is* two charges on one composite geometry–gauge connection — mass on the metric sector, quantized holonomy charge on the gauge sector — with no slot for a size; and the electron is not a small object *in* space: its entire structure — dyadic depth, winding, cascade level — lies along the two non-spatial directions of the bulk, the scale interval I_r and the phase circle S^1_θ (GG-A2-GG6's theorems). In space it therefore *must* appear as a point: all of its extension is orthogonal to space. The mass is a basin level, not field self-energy — the divergence crisis dissolved, not renormalized away; the spin a double-cover label, not a rotation — no superluminal surface needed. The operational claim, that the structural form factor is identically unity at every scale, is proved via a lemma, Readout Locality (RL: the bulk-to-boundary readout introduces no 4D length scale), *derived* from the constitutional axiom AX-1 (Locality and Causality) — with one technical step (the static-limit factorization) registered as open. The sharp edge is pre-registered: *no substructure will ever be found, at any scale* — compositeness models predict a scale; this framework forbids one forever.

Predictions and kill criteria. The paper is killed by: (F1) any observed electron decay ($\tau_e > 6.6 \times 10^{28}$ yr, Borexino); (F2) any confirmed substructure at any scale; (F3) a fourth charged lepton (GG-P2-N3's fences inherited); (F4) m_e off the QD value beyond the declared 1.9×10^{-4}, or α^{-1} off its QD completion, once the $> 5\sigma$ Rb/Cs discrepancy in α is resolved; (F5) a demonstrated flaw in the AX-1 derivation of Lemma RL, demoting the pointlikeness theorem to conditional status; (F6) a confirmed electron–positron asymmetry (mass, charge, or g), killing the Q6 answer before it killed CPT. The electron $g-2$ (0.13 parts per trillion) is engaged as the empirical anchor of structurelessness, not claimed as a GG-Theory computation.

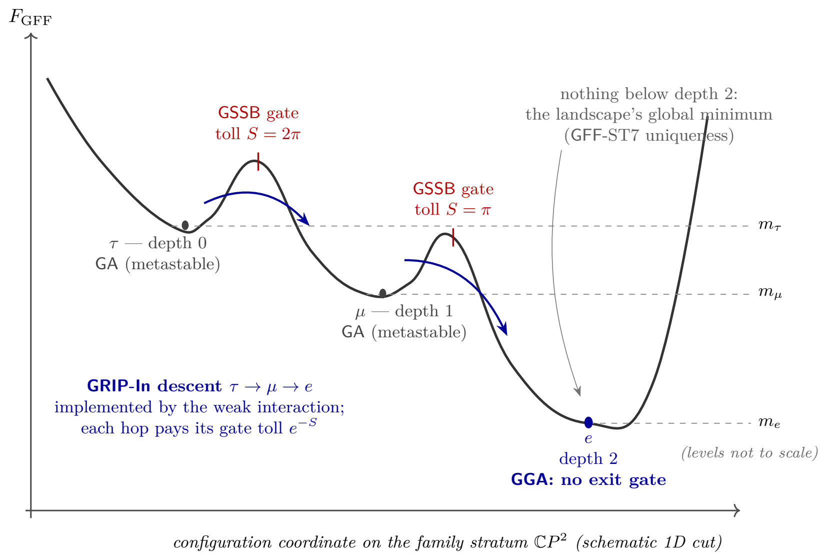
What is new in this paper. (i) The conjunction thesis stated and defended: standard physics has fragments, each presupposing inputs the geometry derives, none connected to the others; no framework has previously explained all six as one theorem-complex about one ground state. (ii) Part VI's derivation of pointlikeness — the first cohort statement converting non-spatial structure into a form-factor prediction, its readout-locality lemma derived from AX-1. (iii) The two-regime unification of Q5 with Q3: field response is within-basin descent, decay through-gate descent, one mechanism. (iv) The complete status ledger (Appendix B): every load-bearing step tagged with its upstream location. (v) The sixth question housed: the positron as the conjugate readout of the one basin (Part V).

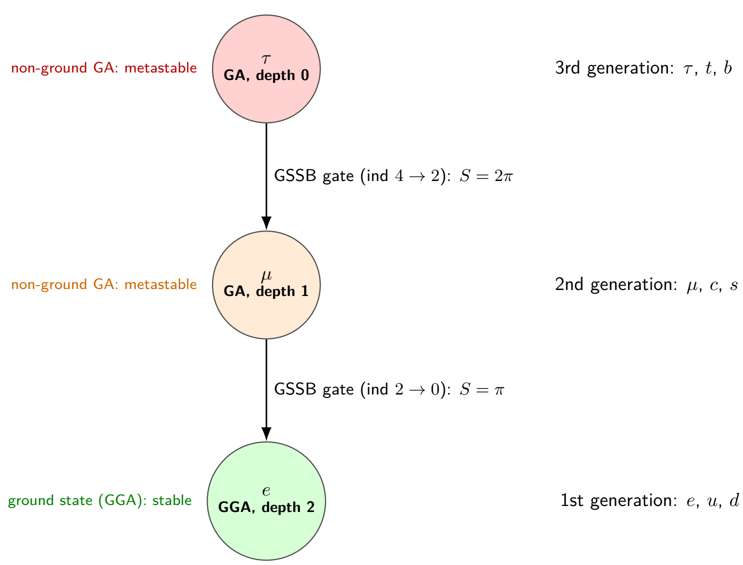
After all, a particle that has carried the same three numbers through every experiment since 1897 deserves better than to have them carried as inputs; it deserves a geometry in which there is exactly one basin at the bottom of the world, and it is sitting in it.

Keywords: electron; positron; identity; absolute stability; pointlikeness; three generations; ground state; GGA; GDOS; GFF; GRIP-In; spin-1/2; $\alpha^{-1} = 137$; Yukawa codebook; GG-Theory

The Whole Electron Story in One Landscape, and the Same Chain as a Morse Diagram

Two drawings of one object. Above: a one-dimensional cut through the GFF Morse landscape on the family stratum. The three charged leptons are the three basins and their floors are the masses; the two GSSB gates carry the tolls $S = 2\pi$ and $S = \pi$; the observed $\tau \to \mu \to e$ decay chain is one descent that pays both and halts in the deepest basin, which has no exit gate. Below: the same chain as its Morse skeleton, three critical points and two gates, accumulating to $S_{\text{tot}} = 3\pi$ and exactly saturating the BI-6 budget. Four of this paper's six questions are visible in the drawing: identity is the one deepest basin, stability is its having no way out, the copies are the two way stations, and the decay hierarchy is the tolls in the exponents. Pointlikeness is the fifth, and it is the statement that the horizontal axis is not a direction of space. In full: Figures 6 and 7, pp. 33–34.





Total cascade action $S_{\text{tot}}(3) = 3\pi$ exactly saturates *the BI-6 budget* $S_{\text{BI}}^{\max} = 3\pi$.

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Part I

The Six Questions and Their Century

What has, and has not, been explained since 1897

1 Preface: to the reader who kept the questions

This paper is written for a particular reader, and it may as well say so at once. You have finished a degree in physics. Somewhere in the first weeks of quantum mechanics — perhaps the day indistinguishable particles were defined, perhaps the day the periodic table fell out of the Pauli principle — you noticed something the course did not pause on: every electron in the universe is *exactly* the same, and the whole edifice silently depends on it. Later you noticed more. The electron never decays, though nearly everything else does. It has two heavier siblings, and only two, for no reason anyone offered. It is a point — not small, but sizeless — and the one time you asked what that does to the field energy, the answer involved a subtraction you were asked not to look at too hard. And it responds to fields: you computed the response a hundred times without once being told what, underneath the vector calculus, *responding* is.

If you asked about any of this, you were told — kindly, and not wrongly — that these are deep waters, that the formalism handles it, and that the problem set is due Friday. So you did what a good student does: you kept the questions and deferred them. This paper is addressed to the version of you that never quite threw them away.

Let us be precise about what kind of questions they are, because their kind is the reason they survived a century untouched. They are not puzzles *within* physics, of the sort a cleverer calculation settles; they are questions about why the inputs of physics are what they are — and a framework whose inputs are inputs cannot answer them, any more than a dictionary can explain why its words mean what they mean. To answer such questions one does not need more cleverness; one needs a deeper layer, in which yesterday's inputs become today's theorems. The claim of this paper — made within one specific framework, GG-Theory, and priced with a candor the reader is asked to hold us to — is that such a layer exists, and that on it the six childhood questions collapse into a single fact: *the electron is the ground state of its corner of the world.* Identity, stability, the two siblings, the mirror twin, the sizelessness, the sensing — one fact, six shadows.

A word on how to read what follows. This is a review and a gateway, not a textbook and not a sermon. Every imported theorem is cited to the companion paper that proves it; every step that is not a theorem is named as what it is — conjecture, hypothesis, empirical input, or interpretation — in the status table that anchors the paper and in the ledger that closes it; and Part VIII lists, in advance, the experimental results that would kill the whole construction. You are not asked to believe; you are asked to audit. The questions were yours before they were ours.

After all, the measure of a foundation is not whether it silences the child's questions, but whether it can finally afford to take them seriously.

2 The six questions

In 1897 J. J. Thomson measured the charge-to-mass ratio of cathode rays and announced a body smaller than the atom (Thomson, 1897) — the particle Stoney had already named from electrolysis (Stoney, 1894) and whose magnetic fingerprint Zeeman resolved the same year (Zeeman, 1897). Within three decades it had revealed the quantization of charge (Millikan, 1913), scattered X-rays like a point (Compton, 1923), diffracted like a wave (Davisson & Germer, 1927; de Broglie, 1925), and forced both the exclusion principle (Pauli, 1925) and the relativistic wave equation (Dirac, 1928) into existence — an equation that promptly predicted, from consistency alone, the electron's own mirror twin (Dirac, 1931), photographed within the year (Anderson, 1933). The particle he found has since become the most precisely characterized object in science — and the questions a child might ask about it remain, in standard physics, substantially unanswered. We state them as they have stood for a century:

Q1 (Identity). Why is every electron exactly identical to every other — and why does it carry precisely the mass $m_e = 0.511$ MeV, the charge $-e$, and spin-$\frac{1}{2}$, rather than any other values?

Q2 (Stability). Why is the electron absolutely stable, to better than 6.6×10^{28} years?

Q3 (Copies). Why do the muon and the tau exist — two heavier particles identical to the electron in every quantum number except mass — and why exactly two, with the ladder terminating at three families?

Q4 (Pointlikeness). Why is the electron a point — no measured size, no substructure, at any scale ever probed — and why does that not cost it an infinite self-energy?

Q5 (Sensing). Why does an electron respond to an electric field at all — what is it about the electron such that it "feels" the field and accelerates toward the nearest proton?

Q6 (The twin). Why does the electron have an antiparticle — the positron, a twin of exactly equal mass and exactly opposite charge, predicted in 1931 and found in 1932 — and what *is* it, if the electron is the unique ground state? (Q6 is numbered sixth because it is the sixth question the century left open in this form; in the body it is taken up in Part V, between the copies and the pointlikeness, where its answer naturally lives.)

The claim of this paper is not that standard physics has said nothing about these questions — Part I's burden is precisely to credit what it has said — but that *the conjunction has never been explained.* Standard physics offers fragments: an ontological convention for identity, a bookkeeping argument for stability, nothing for the generations, an experimental upper bound for the size, a sign rule for the force — each presupposing unexplained inputs, none connected to the others. Within GG-Theory the six questions have one answer, and the fragments become consequences.

Who this paper is for. This paper is written as a review article, for the first-year graduate student in physics — for the critical thinker who finished a degree carrying exactly these six naive, fundamental questions and was told, by silence or by syllabus, to move on. Part I requires undergraduate quantum mechanics; imported machinery is introduced at the point of use, with its rigorous development cited rather than reproduced. The intended outcome is a cleared mind, not a converted one: the status table of §3 prices every claim, the kill criteria of Part VIII say where the framework can be shot, and the reader who wants the full treatment will find, in the cohort papers of Part II, the few years of serious work that these questions have always deserved.

3 The honest status table

The paper's method is a status discipline inherited from its sister paper GG-P2-N3 (Arisaka, 2026, P2-N3): every load-bearing step is tagged as **THM** (theorem, with grep-verified upstream location), **CONJ** (named conjecture), **POST** (named postulate or hypothesis), **EMP** (empirical input), or **INT** (interpretive reading), and the tag travels to every layer of the paper including the abstract. Table 1 is the paper in one page; Appendix B is its machine-checkable expansion.

4 The central claim: the electron as the ground state of nature as an open-system observable

It is worth stating, in one place, the recognition this paper shares with the whole GG-Theory cohort. No physical system is closed — so the four-dimensional world is a lawful projection (OGGEP, AX-3) of the six-dimensional bulk, and that projection *is* observation itself; its dynamics is the open-system law GDOS (GG-A5-GDOS), forced by the geometric Gi-4 (GG-A6-GRIP) and quantum-information Qi-4 (GG-A7-Qi4) pillars. It follows that the electron — its mass, its identity, and its stability — is a *registered observable* of one projection: the ground state of nature, fixed by the geometry rather than chosen — which is why this paper can derive it, and why a single clean measurement can refute it. The funnel below is shared, in structure, with the companion papers GG-A9-SM, GG-A10-Cosmos, and GG-A11-Origin; only the payload differs.

5 The claim of this paper, and its fences

The defensible strong claim — and the only claim this paper makes — is the conjunction:

> *The electron's identity (with its values), its absolute stability, its excited copies (with their count), its exact pointlikeness, and its response to fields — with the positron as the same fact read in the mirror — are six faces of one fact: the electron is the unique ground state — the* GGA *— of the charged-lepton stratum of the boundary. No prior framework has explained these five together, because no prior framework had the one fact of which they are faces.*

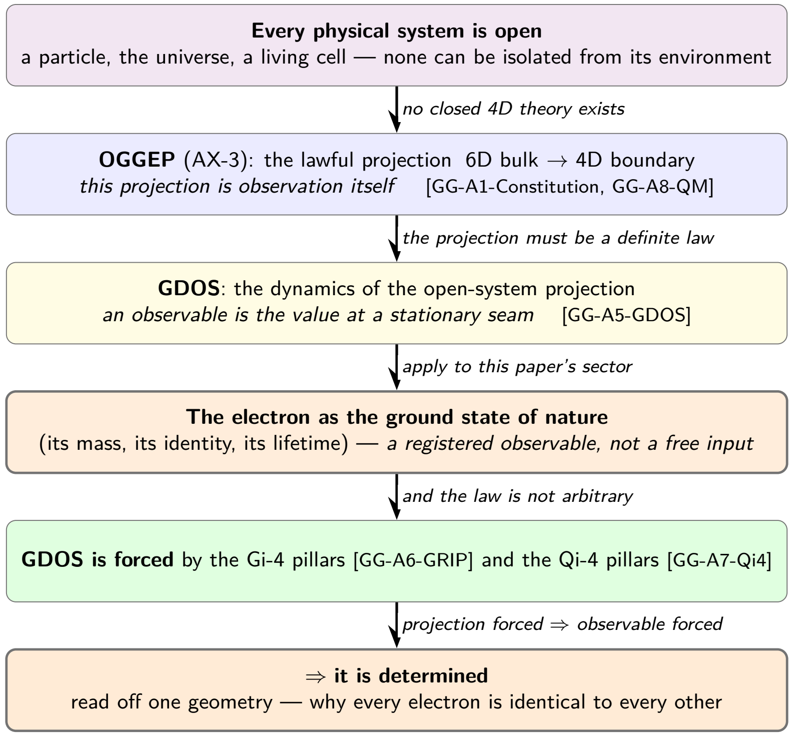

Figure 1: The central claim, as one deductive funnel, shared across the GG-Theory cohort. Because no physical system is closed, the four-dimensional world is a lawful projection (OGGEP, AX-3) of the six-dimensional bulk, and that projection is observation itself; its dynamics is GDOS, forced by the Gi-4 and Qi-4 pillars. The same funnel opens the companion papers GG-A9-SM, GG-A10-Cosmos, and GG-A11-Origin; only the payload differs — here, the electron as the ground state of nature.

The fence inventory, complete, in one place: two empirical inputs (observed CP violation; $N_\nu = 3$) and the coupling clause plus the integrality theorem L-INT with its named topological residue (R-INT), all imported from GG-P2-N3 with Q3; one lemma new to this paper (RL, Readout Locality), derived in Part VI from the constitutional axiom AX-1, with its one formalization step registered as open (D-P3-1); one interpretive layer (the open-system arrows of Part VII — radiative dissipation for motion, scale-sector GRIP-In for decay — glosses on the derived geodesic law, not the law itself); the QD-layer residual 1.9×10^{-4} on m_e, declared wherever the mass is mentioned; and the QED credit for the sign rule, stated wherever the force is mentioned. Nothing else in the paper is conditional, and nothing conditional is stated as unconditional. The paper's kill criteria are pre-registered in Part VIII; the fifty-year question deserves a paper that cannot be embarrassed, and the fences are how it earns that.

After all, a claim in physics is worth exactly what its declared conditions make it worth — and the discipline of declaring them is not the tax this paper pays for its strong thesis; it is the reason the thesis can be strong.

6 The cohort inheritance and the roadmap of the ten Parts

Before the inheritance is unpacked (Part II) and the six questions are taken up one by one (Parts III–VII), it is useful to lay out two reader-orientation maps on the same opening: a panorama of the twenty-two-paper cohort in which this paper stands (§6.1, Figure 2), and a panorama of the ten Parts of the present paper (§6.2, Figure 3). A reader of any later Part should be able to flip back to this Section and orient themselves in both directions: which cohort companion carries which imported result, and where the present argument stands in the ten-Part arc.

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 electron paper: the deployment of the derived machinery on the oldest particle in physics, under the thesis that the electron is the unique ground state — the GGA — of its boundary 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 relative, 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 two non-spatial directions carry everything this paper says about the electron, GG-A3-BI6 proves the anomaly cancellation that locks the sectors together, and GG-A4-Euclid tells the history. *One boundary law:* AX-3 forces GG-A5-GDOS — the open-system dynamics that Part III uses for stability and Part VII for radiation — organized by the two pillar papers GG-A6-GRIP (the geometric pillars: GFF, GRIP-In, the GGA) and GG-A7-Qi4 (their quantum-information twins). *Three readouts:* GG-A8-QM recovers textbook quantum mechanics, GG-A9-SM derives the Standard Model's 28 parameters — the codebook from which this paper's y_e, m_e, and α come — and GG-A10-Cosmos derives the cosmological inventory; 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, third in its row after the collider falsifier GG-P1-KK and the family-number derivation GG-P2-N3; the teal frame carries the cosmology siblings GG-C1-Kaxion, GG-C2-Hubble, and GG-C3-BH. 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; when a fence is restated, it usually traveled up the $N{=}3$ arrow from GG-P2-N3 — 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 electron's quantum mechanics runs on — the gauge phase from the circle's quarter-turn, the state-space i from the causal clock — and the shared complex structure their forced agreement places on the charged sectors is exactly what the electron, as the lightest charged state, carries. GG-P5-CPT (Arisaka, 2026, P5-CPT) gives the electron its twin: the positron is the first receipt of that circle–clock handshake, with C, P, and T read as orientation reversals of the three real bulk factors. 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.

Table 1: The six questions: honest standard status, GG-Theory answer, and claim status. Tag vocabulary in §3; full per-step ledger with verified upstream locations in Appendix B. Each row pairs what standard physics has established with what this paper claims on top of it, and the last column says at what grade the claim is held, so a reader can see at once which answers are proved here, which are inherited from a companion, and which are still owed.

Q	Standard physics (credited)	GG-Theory answer	Status
Q1 identity	One-field ontology explains sameness; m_e, e, spin-$\frac{1}{2}$ remain free inputs	Unique GGA readout; y_e, m_e from codebook; e derived; spin-$\frac{1}{2}$ from $\mathrm{Spin}(1,5) = \mathrm{SL}(2,\mathbb{H})$	THM (GDOS-internal) + codebook; spin: THM; m_e residual 1.9×10^{-4} declared
Q2 stability	Lightest charged + charge conservation (correct; presupposes Q3's spectrum)	Ground basin has no exit gate; GRIP-In halts	THM given GFF-ST7; Q3 conditioning inherited
Q3 copies	None. Three families an input since 1936	μ, τ = depth-1, depth-0 basins of the electron's landscape; $N = 3$ forced	Imported from GG-P2-N3: EMP + AX (coupling clause) + THM (L-INT, residue R-INT); reachability INT
Q4 point	None. Pointlike by construction; renormalization sidesteps the self-energy crisis; bounds only	All structure along non-spatial I_r, S^1_θ; mass = basin level; spin = double-cover label; $F(q^2) \equiv 1$	THM via Lemma RL, derived from AX-1 (one formalization step open, D-P3-1); ingredients THM (A2, A4, A9) + AX-2 coupling completeness (GG-A5-GDOS)
Q5 sensing	Sign rule derived (QED, credited); existence, quantization, strength of coupling unexplained	Force law derived as composite geodesic motion (Newton & Coulomb in parallel from one bulk; AX-2); U(1), quantization, α derived; arrows in their sectors (radiation: motion; GRIP-In: decay)	THM (GG-A5-GDOS Part VI) + codebook; arrow readings INT; quantum sign reading QED's, credited
Q6 twin	Necessity at the formalism level (QFT) + pairing constraints (CPT), both credited; what the twin *is* unaddressed	Twin forced in the real bulk, pre-quantization (handshake, imported GG-P5-CPT); positron = conjugate readout of the same basin	THM (imported: T-P5-A/B/C, C2) + INT (same-basin reading, named); promotion owed (D-P3-4)

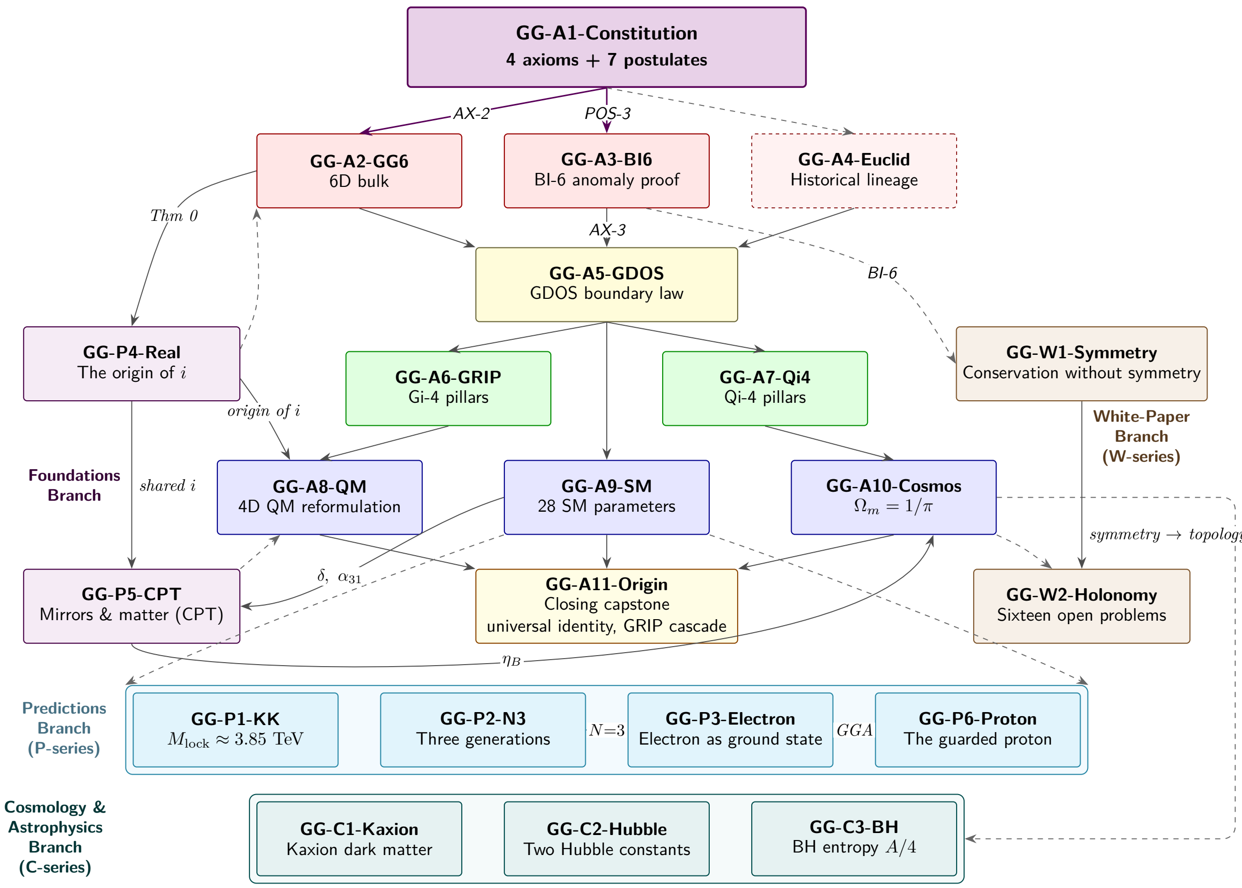

Figure 2: The twenty-two-paper cohort map of GG-Theory. The constitutional root GG-A1-Constitution (violet, top) supplies the four axioms and seven postulates from which the rest of the cohort descends: the GG6 Trio (GG-A2-GG6, GG-A3-BI6, GG-A4-Euclid, red) realizes the bulk geometry; GG-A5-GDOS (yellow) 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 (Arisaka, 2026, 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. The branches this paper does not draw on are on the map all the same, and are cited here at roster level, which is all they can honestly claim from it: Arisaka, 2026, C2-Hubble; Arisaka, 2026, C3-BH; Arisaka, 2026, P1-KK.

6.2 Roadmap of the ten Parts

The rest of the paper is organized into nine further Parts, and the walk through them is plotted in Figure 3. The present Part — the entrance — is nearly done: it has put the six questions and their century on the table, graded what standard physics does and does not explain in the honest status table, drawn the central claim as one funnel, fenced it, and laid out the two orientation maps of this closing section. Part II gathers the inheritance: the framework minimum — the six-dimensional bulk with its two non-spatial directions, the open-system boundary law, the pillar structure, and the codebook — and the sister paper's $N = 3$ with its fences, so that every later import has its provenance stated once and its conditioning attached.

Part III is the paper's center of gravity, and it is highlighted in the roadmap because it establishes the one fact of which every later answer is a face: the ground-state uniqueness. Identity and absolute stability are proved there as one theorem — every electron is the same readout because each is the unique deepest basin, the GGA, of the charged-lepton stratum (Q1), and no exit gate leads out of that basin, so the electron cannot decay (Q2). The derived values — the Yukawa, the mass, the charge — and the horizon-independence corollary live in the same Part, because they are what identity *means* once it is a theorem.

Four Parts then read the same fact from four more sides. Part IV turns to the excited copies: μ and τ as geometrically excited electrons, the ladder that ends at three — Q3, imported from GG-P2-N3 with its conditioning stated verbatim — and the muon lifetime as a GRIP-In observable, the rate at which a non-ground copy descends to the terminus. Part V is new at this version and turns the mirror sideways: the origin of positrons — the sixth question, the one the century answered before asking — with the origin of antiparticles imported at theorem grade from the CPT companion GG-P5-CPT, and the positron read as the conjugate readout of the electron's one basin (Q6), so that the sixth question collapses into the first. Part VI is the paper's own derivational core, on the question no framework had touched: why the electron is a point in space and nowhere else — pointlikeness derived from non-spatial structure (Q4), with its observable shadow pre-registered. Part VII answers why the electron moves: the sixth dimension as the electromagnetic fiber, the equivalence principle for charge, and the force law as composite geodesic motion (Q5), with the open-system layer stating what descends, and where.

The last three Parts weigh, close, and document. Part VIII is the discussion: the significance of the six answers, uniqueness against prior approaches, the sharp contrast with supersymmetry and string models, the pre-registered falsification table, the open problems, and the common objections with their responses. Part IX concludes: why the questions waited a century, the view from the last page, the conclusions in plain English, and the fifty-year arc. Part X is the workshop — the appendices: the abbreviations, the claim-status ledger, the complete derivations for Q1–Q5 (Q6's derivation is the CPT companion's, imported in Part V), and the empirical anchors. Read in order, the ten Parts compose a single self-contained argument; read by need, each Part names its imports and can stand a visit on its own.

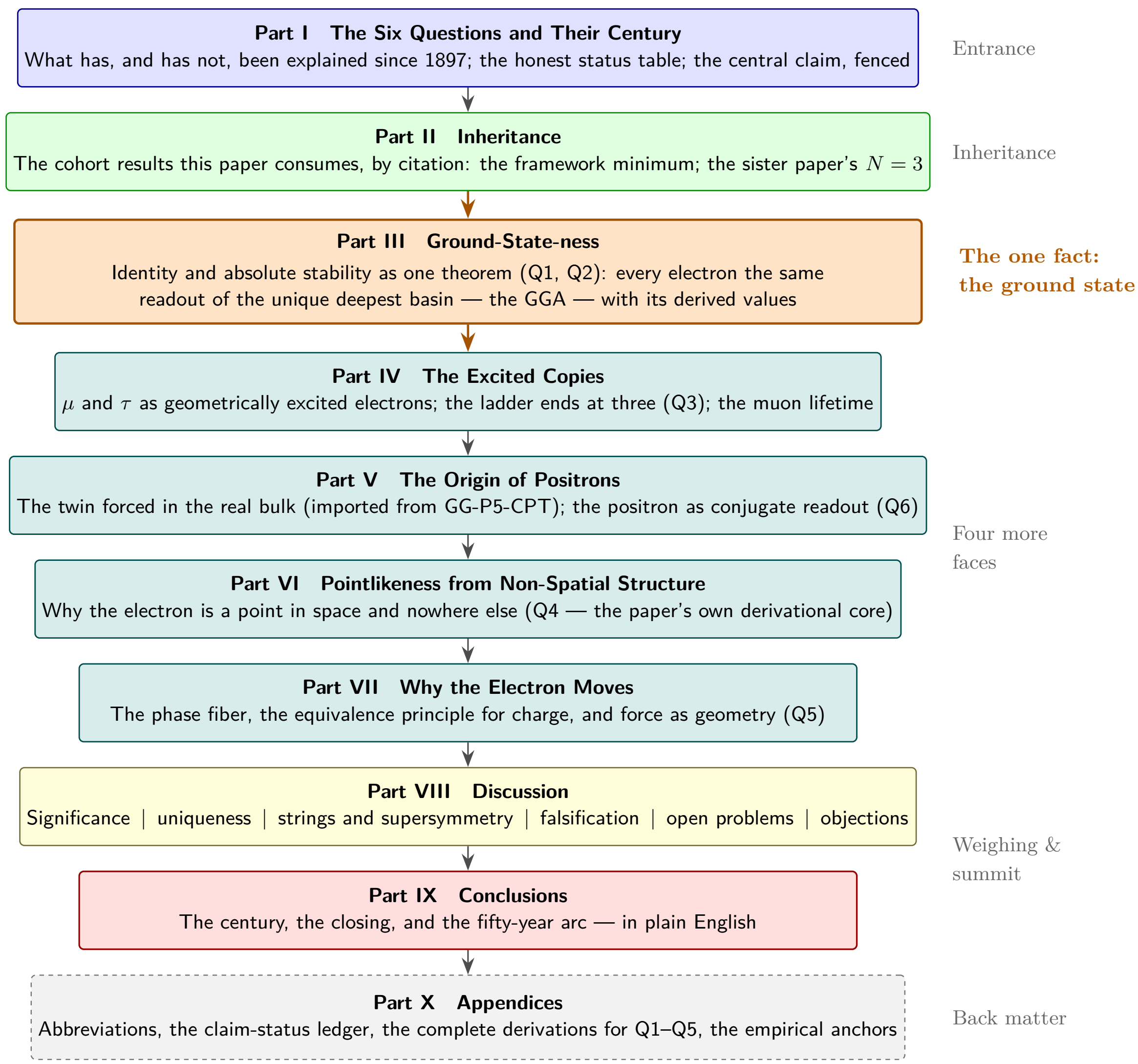

Figure 3: Roadmap of the ten Parts of GG-P3-Electron. The argument develops in six phases. *Entrance* (Part I): the six questions and their century, the honest status table, and the central claim with its fences. *Inheritance* (Part II): the cohort results this paper consumes, by citation, and the sister paper's $N = 3$ with its fences. *The one fact* (Part III, highlighted): ground-state-ness — identity and absolute stability proved as one theorem (Q1, Q2), with the derived values and the horizon-independence corollary. *Four more faces* (Parts IV–VII): the excited copies and the terminus of the ladder (Q3), the origin of positrons — the twin forced in the real bulk and read as the conjugate readout of the one basin (Q6) — pointlikeness from non-spatial structure (Q4), and why the electron moves (Q5). *Weighing and summit* (Parts VIII–IX): the discussion — significance, uniqueness, the contrast with strings and supersymmetry, falsification, open problems, objections — and the conclusions, from the century to the fifty-year arc. *Back matter* (Part X): the appendices, from the claim-status ledger to the complete derivations for Q1–Q5. Part III is highlighted because it carries the paper's central claim — the ground-state uniqueness of §4: the electron as the unique deepest basin, the GGA, of its stratum — of which the answers of Parts IV–VII are four further faces, and on which every later Part stands.

7 Part I in plain English: what was never explained, and what this paper is for

Six facts about the electron are so familiar that a physics course states them without pausing. Every electron is exactly like every other. None has ever been seen to decay. There are two heavier copies and only two. It behaves as a point, with no measured size. It responds to fields by a law nobody derives. And its antiparticle exists because an equation demanded it.

None of the six is a mystery in the sense of being unmeasured. Each is measured to extraordinary precision. What none of them has is a reason. The Standard Model takes the mass, the charge and the family count as inputs — numbers written in by hand and then used with great success — and a theory that begins by writing a number down cannot afterwards explain it.

This Part answers nothing. It states the six questions in the form a working physicist would recognize, gives standard physics full credit for the part of each that it does explain, and marks in a table what is left over. That table is the honest scorecard, and the rest of the paper is an attempt to fill in its last column. Where an answer rests on a companion paper rather than on this one, the table says so.

Part II
Inheritance

The cohort results this paper consumes, by citation

8 Framework minimum

This is a companion paper: it derives nothing upstream and re-derives nothing imported. The reader needs the following minimum, stated with the source of each element; every attribution below was verified against the cited paper at its stated location rather than from memory (the per-item registry is Appendix B).

The bulk and its two non-spatial directions. The constitutional axioms of GG-A1-Constitution (among them MSMF, "Maximum Symmetry, Minimum Freedom") (Arisaka, 2026, A1-Constitution) force a six-dimensional bulk (Theorem 1 of GG-A2-GG6), $\mathcal{M}_6 = \mathcal{M}_4 \times I_r \times S^1_\theta$, with the canonical, parameter-free metric (its Theorem 2)

$$ds_6^2 \;=\; e^{-2r}\,\eta_{\mu\nu}\,dx^\mu dx^\nu \;+\; dr^2 \;+\; d\theta^2 \tag{1}$$

(Arisaka, 2026, A2-GG6). The two extra directions are a geometrized scale/RG direction I_r and a compact phase direction S^1_θ — *not spatial*, the load-bearing fact of Part VI. The bulk Lorentz group satisfies $\mathrm{Spin}(1,5) \cong \mathrm{SL}(2,\mathbb{H})$ (quaternionic; A2's magic-square proposition). The integer ledger $(M,N,L;J,K) = (1,3,5;7,35)$ is Diophantine-unique (A2, Theorem 6), with BI-6 anomaly closure proved in GG-A3-BI6 (Arisaka, 2026, A3-BI6). **Figure 4** draws the bulk in cross-section — the one picture to keep in mind through Part VI.

Derived constants. GG-A4-Euclid (Arisaka, 2026, A4-Euclid) supplies the GU-5 constant-absorption lineage $\{c, G_N, \hbar; k_B, Q_B\}$ and the theorem T-Euclid-4 that the elementary charge is derived, not primitive.

The open-system runtime. GG-A5-GDOS (Arisaka, 2026, A5-GDOS) establishes GDOS (= Geometric Dynamics of Open Systems), the boundary law of open-system dynamics; GG-A6-GRIP (Arisaka, 2026, A6-GRIP) codifies its four pillars, of which this paper consumes the GFF landscape (= the Geometric Free-energy Functional — the master landscape whose valleys are the stable objects of the boundary) with its structure theorem GFF-ST7 (unique deepest attractor per stratum), the regime definitions def:GRIPin/def:GRIPout (GRIP-In = relaxation on a fixed landscape (Arisaka, 2026, A7-Qi4); GRIP-Out = the rarer events that rebuild the landscape itself), and the definition def:GGA; the regime theorem T-GGA-as-Ground-State is proved in the capstone GG-A11-Origin

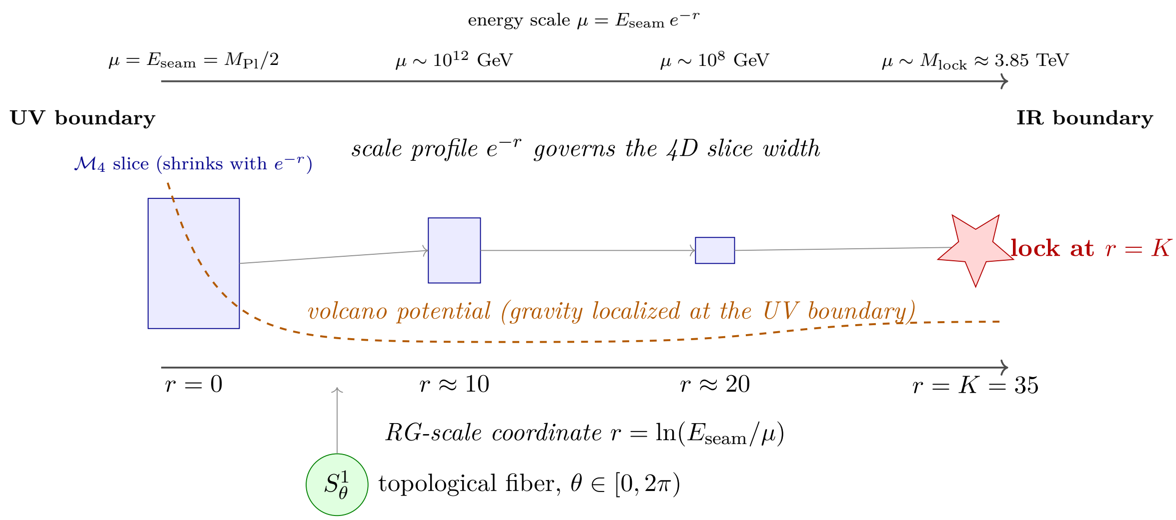

Figure 4: The 6D bulk in cross-section, adapted from the bulk paper. The horizontal axis is the scale direction I_r in the coordinate $r = \ln(E_{\rm seam}/\mu)$ with $E_{\rm seam} = M_{\rm Pl}/2$ — a position in *resolution*, not in space — from the UV boundary at $r = 0$ to the IR lock at the integer scale depth $r = K = 35$ of the ledger. Four representative 4D slices shrink with the scale profile e^{-r} of the canonical metric; the phase circle S^1_θ (green) is fibered over every r, with one representative copy drawn. The slices are sketched at a non-physical aspect ratio for clarity: the true shrinkage at $r = 35$ is $e^{-35} \approx 6.3 \times 10^{-16}$. Everything the electron *is* — its dyadic depth, its winding, its basin — is structure along these two non-spatial directions.

(Arisaka, 2026, A11-Origin). We record, as GG-P2-N3 did, that GG-A5-GDOS's open problem O3 lists strict GFF Morse-positivity as unsettled.

The codebook. GG-A9-SM (Arisaka, 2026, A9-SM) derives the Standard-Model parameter sheet from the ledger; this paper consumes its charged-lepton codebook (§12.1), its dyadic-closure α theorem (§12.2), its identity section, its forces section, and its weak-as-GRIP-In doctrine. GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) closes the cosmological boundary and is cited for cohort context; GG-C1-Kaxion (Arisaka, 2026, C1-Kaxion) deploys the GGA vocabulary on the dark-matter stratum and is the bibliographic precedent for its cohort use. A reader meeting the program's acronyms will find the canonical Dictionary of Program-Defined Acronyms — each entry with a plain-English physics intuition — in GG-A2-GG6, Appendix B. Figure 2 — the closing map of Part I — is the whole program in one view; the version-by-version inheritance ledger, grep-verified entry by entry, remains Appendix B's.

9 The sister paper $N = 3$ and its fences

GG-P2-N3 (Arisaka, 2026, P2-N3) is this paper's immediate predecessor and closest relative: it proves — under declared conditioning — that the family number is $N = 3$, by three legs (CP-violation lower bound; GDOS Morse/budget upper bound; codebook cross-check). Everything this paper needs from it is imported in Part IV *with its conditioning stated verbatim*; the division of labor is that GG-P2-N3 owns "why three" and this paper owns "why the terminus is what it is." The two papers share their ontology — basins as generations, gates as decays, the GGA as the electron — and their honesty discipline; neither re-proves the other's theorems, and each cites the other's fences.

This is all the apparatus the paper needs. What follows is the six questions themselves — and the reader who keeps one image, the landscape whose deepest valley is the electron, will find every later Part examining it from another side.

10 Part II in plain English: what this paper borrows, and exactly where from

This Part contains no new physics, and that is the point of it. The argument that follows needs a six-dimensional stage, two directions that are not space, a rule for how a large system looks to a small observer inside it, and a set of integers. All four are established elsewhere in the cohort, and reproving them here would make the paper longer and the audit harder.

So the Part is a list of imports. Each entry names what is taken, the paper that establishes it, and the exact place in that paper where it is established — a theorem number, not a general citation, because a general citation is what lets a borrowed result quietly change strength on the way in.

A reader in a hurry can skip it and return when something downstream turns out to depend on an imported fact. A reader checking the work should not skip it. This is where the paper's dependencies are exposed, and any circularity — a result borrowed from a companion that had itself borrowed it from here — would have to appear in this list before it could hide anywhere else.

Part III
Ground-State-ness

Identity and absolute stability as one theorem (Q1, Q2)

11 Identity: every electron is the same readout

11.1 The standard answer, credited in full

We begin where an honest treatment must: quantum field theory has a real partial answer to Q1, and it deserves to be stated at its full strength before anything is added to it. In QFT all electrons are excitations of one underlying field. Two electrons cannot differ in mass or charge for the same reason that two ripples on one pond cannot disagree about what water is. Exact likeness is automatic, and the formalism enforces it to all orders, with the spin-statistics theorem (Pauli, 1940) fixing how the identical copies must be counted. Any reader who has heard this answer and found it sufficient is in good company; it is correct as far as it goes.

What the field answer does not do is explain the *content* of the likeness. It relocates Q1 into three questions it cannot address: why is there exactly this field; why does it carry the mass m_e and the charge $-e$ rather than any other values; and why does it transform in the spin-$\frac{1}{2}$ representation rather than any other entry of Wigner's classification of admissible representations (Wigner, 1939)? In the Standard Model all three are free inputs. The field ontology explains *sameness*; it explains none of the sameness's content. The remainder of this Part supplies the content.

11.2 The GGA statement

The GG-Theory answer rests on the ground-state refinement of the cohort's attractor vocabulary. GFF-ST7 of Arisaka (2026, A6-GRIP) guarantees every boundary stratum a unique deepest attractor; Definition def:GGA of Arisaka (2026, A6-GRIP) names it the Ground Geometric Attractor,

$$\mathsf{GGA}(\Sigma) \;:=\; \operatorname*{arg\,min}_{x\in\Sigma} F_{\mathrm{GFF}}(x), \tag{2}$$

the unique global minimum of the geometric free-energy functional on the stratum Σ; and the capstone Arisaka (2026, A11-Origin) proves the regime theorem (T-GGA-as-Ground-State) that the cascade output at each layer is not *a* stable basin but *the* ground state. GG-A9-SM deploys exactly this refinement for the electron (Arisaka, 2026, A9-SM, the section "The geometric origin of identity").

Theorem 11.1 (Identity as unique-readout; status: theorem within GDOS (T-Electron-1))**.** *On the charged-lepton boundary stratum Σ_ℓ, the GFF Morse landscape admits exactly one GGA. Every* *electron, anywhere on the 4D boundary, is the readout of that single attractor: its mass is the GFF level at the minimum, its charge is the integer-normalized* $\mathrm{U}(1)_{\mathrm{EM}}$ *eigenvalue on the unique stable cascade leg, and its spin label is fixed by the boundary action of the bulk spinor group. Consequently no two electrons can differ in any intrinsic property.*

Proof, by assembly of cited results. Uniqueness of the ground attractor is GFF-ST7 (Arisaka, 2026, A6-GRIP); the identification of the electron with the depth-2 GGA of the $\mathbb{C}P^2$ family stratum is the generation-to-cascade assignment of GG-A9-SM (its labeled lepton cascade-depth section, imported here as Part IV below); the readout reading of boundary particles is the universal-identity statement of GG-A8-QM (Arisaka, 2026, A8-QM), recognized there as theorem T-A8.9 (cohort ID T-QM-9). The conjunction is the claim. ■

The chemistry analogy of GG-A9-SM is exact and worth repeating, because it is the right intuition for everything that follows: a molecule has many stationary electronic configurations, but every water molecule in the universe is identical — and indefinitely stable — because its electrons occupy not merely *a* stable configuration but *the* lowest one. The GGA is "ground state" promoted to a constitutional principle.

Physics intuition. The reader has met this structure twice in graduate training, under other names. In condensed-matter language, F_{GFF} is an effective free energy on an order-parameter space, and Eq. (2) selects its global minimum — the electron is to its stratum what the true vacuum is to a Landau functional, with the muon and tau as its metastable phases. In chemistry language, the stratum is a configuration space and the GGA its ground-state conformation. The one unfamiliar move is that the landscape's coordinates are not positions in space but structural directions of the bulk — scale and phase — so the valleys are not *places*; they are *kinds*. A particle species is a valley; its mass is how deep the valley floor sits; and "every electron is identical" is the statement that one valley has one floor. **Figure 5** draws the complete runtime this paper consumes — the descent, the two regimes, and the halt at the GGA.

Three remarks fence the claim honestly. First, Theorem 11.1 is a theorem *within* GDOS: it consumes the open-system framework of GG-A5-GDOS (Arisaka, 2026, A5-GDOS) and the pillar structure of GG-A6-GRIP, with their own declared axiomatic bases. It is not, and is not offered as, a derivation acceptable to a reader who rejects the framework; it is the statement that *inside* the framework, identity stops being an input. Second, the uniqueness statement GFF-ST7 is a structure theorem of GG-A6-GRIP; its Morse-positivity underpinnings connect to the open problem O3 of GG-A5-GDOS, which records the strict GFF Morse-positivity question as unsettled — the same honesty note that GG-P2-N3 carries (Arisaka, 2026, P2-N3, its Postulate 6.3 and Appendix E). The fence travels with the import. *Third*, a remark that will look like a liability and is in fact the theorem's sharpest feature: the attractor is a property of the boundary *landscape*, whose coordinates are the non-spatial directions of the bulk — scale and phase — and not positions in space at all. Nothing in Theorem 11.1 refers to where an electron sits, or to whether two electrons have ever shared a causal past. That is exactly what is needed, because the sameness of the electron is not only a laboratory fact; it is a fact across the whole sky, including regions that were never in causal

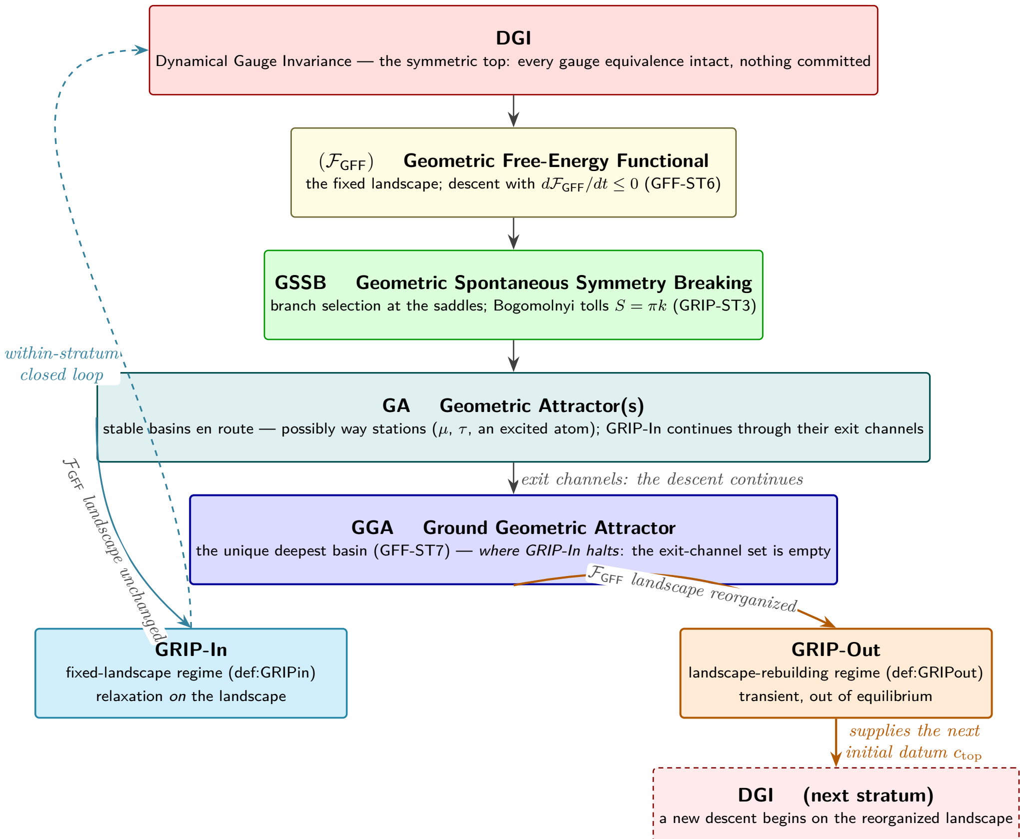

Figure 5: The GRIP cascade and its two regimes, in one picture (adapted from GG-A6-GRIP (Arisaka, 2026, A6-GRIP); the eighteen-layer deployment is GG-A11-Origin (Arisaka, 2026, A11-Origin)). The central column is the runtime this paper consumes: from the fully symmetric top (DGI), the system descends the fixed landscape $\mathcal{F}_{\mathsf{GFF}}$, selects branches at the GSSB saddles, and is captured into stable basins (GA). From a *non-ground* GA — a muon, an excited atom — the descent continues through the basin's exit channels (GRIP-In, the weak interaction being Nature's implementer on the matter strata); at the GGA, the unique deepest basin of GFF-ST7, the exit-channel set is empty and GRIP-In halts. Only GRIP-Out can act thereafter, reorganizing the landscape itself and starting the next stratum's descent. In one sentence: GRIP-Out opens the landscape; GRIP-In finishes the journey; the GGA — the electron, on its stratum — is where the journey ends.

contact — and no account built on shared history could reach them. The following corollary states the point, and connects it to the companion cosmology.

Corollary 11.2 (Horizon-independence; the second horizon problem, status: within GDOS)**.** *Because the charged-lepton GGA is the unique deepest basin of a landscape indexed by scale and phase — not by spatial location — Theorem 11.1 holds pointwise on the entire boundary, independently of causal structure. Two electrons in regions that never exchanged a signal, even regions permanently beyond each other's horizon, read out the* same *attractor, because they are boundaries of the* same *six-dimensional bulk. The identity is guaranteed by the geometry, not negotiated by any history.*

This is the particle-scale face of what the companion GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) names the *second horizon problem*: the observation that the sky is everywhere made of the same things — every electron of one mass and charge, every atom radiating the same lines — across regions the temperature horizon problem shows were never in contact. There the puzzle is closed in two moves: this *mold* (one specification per object, from one bulk) and an *ordering* argument (the derived grand-unification-scale launch means the inflationary stretch acted before any matter existed, so the agreements were inherited, not negotiated). Theorem 11.1 supplies the first move at the level of the single electron; GG-A10-Cosmos's Section on the second horizon problem carries the cosmological half. The empirical exposure is shared and already stringent: quasar-absorption spectroscopy bounds any spatial variation of the dimensionless combinations that carry the electron's identity — the fine-structure constant α and the electron-to-proton mass ratio — across the observable universe at the 10^{-5}–10^{-6} level, so a single confirmed variation would refute the mold here exactly as it would there.

That exposure is also the cleanest way to see what separates this reading from the string landscape. A framework with a single vacuum must return one value of α everywhere, and is exposed to a single discordant measurement; a framework with of order 10^{500} vacua and no dynamical selection principle (Kachru et al., 2003) accommodates the same uniformity only by having our whole observable patch descend from one nucleation event in an eternally inflating background — internally consistent, but at the price of the measure problem, which defers prediction of any further constant. The identity we measure is thus, in the one reading, a necessity exposed to falsification and, in the other, an inheritance immune to it. The companion GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) develops the contrast in full, in the closure-mode form that prices the landscape rather than refuting it.

12 The content of identity: the derived values

Identity-as-uniqueness would be consistent with *any* values of $(m_e, e, \frac{1}{2})$. The framework's stronger claim is that the values themselves are readouts. This section assembles the three value statements with their individual statuses; none of them is new to this paper, and each is grep-verified at its upstream location (Appendix B).

12.1 The mass

GG-A9-SM's minimal first-order codebook gives the electron Yukawa

$$y_e^{(1)} \;=\; \frac{N}{L^3\,2^{\,J+L+1}} \;=\; \frac{3}{5^3\cdot 2^{13}} \;=\; \frac{3}{1\,024\,000}, \tag{3}$$

built entirely from the OGN-5 integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$, whose Diophantine uniqueness is Theorem 6 of GG-A2-GG6 (Arisaka, 2026, A2-GG6). The QD (Quantum Descent) completion layer of GG-A9-SM multiplies this by the structurally constrained rational $\mathcal{R}_e = 1+\frac{M}{2^J L} = \frac{641}{640}$, yielding

$$m_e^{\mathrm{QD}} \;=\; 0.511097845\ \mathrm{MeV}. \tag{4}$$

The CODATA 2022 value is $m_e c^2 = 0.51099895069(16)$ MeV (CODATA, 2022); the codebook value agrees at the 1.9×10^{-4} relative level — four significant figures, with the residual in the fourth figure declared, not hidden. We state plainly: the mass derivation is *codebook-level* — derived modulo the named A9-local lemmas of the QD layer — and the 1.9×10^{-4} residual is the current precision of that layer. Nothing in this paper sharpens it; Part VIII registers it as a kill criterion at exactly this declared precision.

What matters for Q1 is not the last digit but the ontology: m_e is the GFF level of the unique ground basin — a property of the landscape, not a dial of a Lagrangian. The same codebook, run at depths 0 and 1, produces m_τ and m_μ (Part IV); the electron mass is the bottom rung of a derived ladder, not an isolated constant.

Physics intuition. The mass-as-level reading is closer to familiar physics than it first appears. Nobody asks what the hydrogen atom's -13.6 eV is "made of": it is the level at which the ground configuration sits, fixed by the structure of the Hamiltonian, and every hydrogen atom carries it exactly because every hydrogen atom occupies the same level. Eq. (4) asks m_e to be read the same way — not stuff accumulated around a point, but the level of the unique lowest configuration, fixed by the integers of the geometry. The codebook then plays the role spectroscopy plays for atoms: read the levels, and check them against the structure that claims to fix them.

12.2 The charge

The elementary charge is not primitive in GG-Theory: T-Euclid-4 of GG-A4-Euclid (Arisaka, 2026, A4-Euclid) derives e within the GU-5 constant-absorption lineage, and the fine-structure value is the dyadic attractor coordinate of GG-A9-SM,

$$\alpha^{-1}(M_Z) \;=\; 2^J \;=\; 128, \qquad \alpha^{-1}(0) \;=\; 2^J + N^2 \;=\; 137.0, \tag{5}$$

with the QD completion bringing the zero-momentum value, as GG-A9-SM reports, to the CODATA 137.036 (Arisaka, 2026, A9-SM; the comparison value is CODATA 2022 $\alpha^{-1} = 137.035999177(21)$ (CODATA, 2022)). Charge quantization — why every electron carries exactly $-e$ and not $-1.07\,e$ — is the topological-integer signature of the cascade: the charge is the eigenvalue of a fixed integer-normalized generator on the unique stable cascade leg. Status: codebook-level for the value;

theorem-level (T-Euclid-4) for the non-primitivity of e. Part VII returns to α as the strength of the sensed force.

12.3 The spin

Spin-$\frac{1}{2}$ — measured as a two-valuedness before it was named (Stern & Gerlach, 1922), carried relativistically by construction since Dirac, 1928 — is the one value the Standard Model cannot even parameterize — it is a representation choice, made by hand from Wigner's list (Wigner, 1939). In GG-Theory the choice is forced by the bulk: the six-dimensional Lorentz group satisfies the accidental isomorphism

$$\mathrm{Spin}(1,5) \;\cong\; \mathrm{SL}(2,\mathbb{H}), \tag{6}$$

the quaternionic entry of the magic 2×2 sequence over the division algebras (Arisaka, 2026, A2-GG6, its Proposition on the magic square and the explicit $\mathrm{Herm}_2(\mathbb{H})$ construction; the classification underneath is Hurwitz's 1898 theorem, cited there). Weyl spinors of the 6D bulk are two-component *quaternionic* vectors; their boundary projection carries an irreducible doublet structure, and the half-integer label of the 4D electron is the shadow of the quaternionic double cover — not a choice among representations but the unique boundary readout of the bulk spinor geometry. Status: structural theorem of A2's group theory.

Physics intuition. The "$\frac{1}{2}$" of spin-$\frac{1}{2}$ never measured a rotation rate; it counts sheets. SU(2) wraps SO(3) twice — a 2π turn lands a spinor on the second sheet ($\psi \to -\psi$), and only 4π brings it home, the fact made tactile by the belt trick. Wigner's classification says a relativistic world is *allowed* such double-sheeted representations; it never says which one nature must use. Equation (6) answers with arithmetic: in dimension six the bulk Lorentz group happens to *be* a 2×2 quaternionic group, whose minimal spinor is the doublet — and the half-integer label we measure in 4D is that double cover, seen from inside the boundary. The dynamical reading — spin *without spinning* — belongs to Q4 and is developed in Part VI; the conjugate orientation of the same double cover is the positron's half of the story, the sixth question of Part V.

13 Stability: no exit gate from the ground basin

A companion at the other end of the same ledger. GG-P6-Proton (Arisaka, 2026, P6-Proton) argues that the proton never decays because its baryon number is a *winding* of the compact geometry — an integer, protected not by a symmetry that could be broken but by the impossibility of continuous motion through the whole numbers; the two mixed anomalies that survive are absorbed by the BI-6 Green–Schwarz inflow, leaving a single $\Delta B \in 3\mathbb{Z}$ door that no proton decay can pass. This Part argues that the electron never decays because there is no gate out of the deepest basin. The two arguments are independent and they are of different kinds — that companion states the pair in one line, *the electron is immortal because its basin has no exit gate; the proton because its winding has no unwinding operator* — so the cohort carries two standing falsifiers rather than one claim made twice, and either could fail without touching the other. That is worth stating plainly, because a framework that has staked two independent absolute-stability claims has staked more than a framework with one.

13.1 The standard answer, credited in full

The textbook explanation of electron stability is two lines long and correct: decay must conserve charge; the electron is the lightest charged particle; therefore there is nothing for it to decay into. Anyone offering a new account of electron stability must first acknowledge that this argument exists, works, and has never failed.

It is nevertheless conditional bookkeeping, in precisely the sense Q1's field answer was: it presupposes the spectrum. "Lightest charged particle" is an empirical fact about the mass ladder, not an explanation of it — why is nothing charged lighter? why does the ladder terminate where it does? — and these questions are exactly Q3, unanswered in the Standard Model for ninety years. Within the SM, absolute stability is an accident of the input spectrum. The empirical anchor meanwhile is spectacular: the Borexino bound on charge-violating decay — the modern end of the symmetry-test program founded by Feinberg & Goldhaber (1959), probing the channel whose theoretical paradoxes Okun & Zeldovich (1978) mapped — places $\tau_e > 6.6 \times 10^{28}$ yr at 90% C.L. (Borexino Collaboration, 2015), more than eighteen orders of magnitude beyond the age of the universe.

13.2 Stability as ground-state-ness

In GDOS the electron's stability is not an accident; it is the second face of Theorem 11.1.

Theorem 13.1 (No-exit-gate; status: theorem within GDOS given GFF-ST7, with Q3's imported conditioning (T-Electron-2))**.** *The electron basin is the unique global minimum of the charged-lepton stratum (the GGA). Unlike the depth-0 and depth-1 basins, it possesses no exit gate: there exists no admissible GSSB gate, of any index and any finite Bogomolnyi toll, leading out of it. GRIP-In halts there. Consequently the electron cannot decay — not because every channel is blocked by a conservation law applied to an unexplained spectrum, but because the landscape contains no downhill direction and no gate.*

The statement and its proof environment live in GG-P2-N3 (Arisaka, 2026, P2-N3, its §9.3: the depth-2 critical point is the GGA, "No exit gate exists; this is why the electron has never been observed to decay"), deployed on the GG-A9-SM cascade assignment (Part IV). What this paper adds is the conjunction reading: identity and stability arrive *together*, as the two faces of ground-state-ness — all copies are identical because there is only one deepest basin, and the copy persists because there is no deeper basin to decay to. In the SM these are two unrelated facts (a field convention and a spectrum accident); here they are one theorem about one minimum.

Physics intuition. Why does a hydrogen atom in its ground state not radiate? Not because a selection rule forbids it, but because there is no lower level to radiate *to*: stability is an absence of destinations. Theorem 13.1 is that statement applied to the electron itself. An excited atom and a muon are, in this reading, the same kind of object — occupants of a level with somewhere lower to go — and the electron, like the ground-state atom, simply has nowhere. The added clause that distinguishes the theorem from the textbook argument is the gate: in GDOS a decay needs not only a destination but an admissible exit, and the ground basin has neither.

Three fences. *(i)* The theorem is GDOS-internal: it presupposes GFF-ST7 and the cascade machinery, and is not claimed to be derivable in SM language. *(ii)* Charge conservation itself is not assumed on top: the boundary $\mathrm{U}(1)_{\mathrm{EM}}$ descends from the derived bulk gauge factor (GG-A2-GG6 Theorem 3; GG-A4-Euclid T-Euclid-4), so the standard two-line argument survives *inside* the framework as a consistency check rather than as the explanation. *(iii)* The claim that the ladder above the electron terminates — that there is no lighter charged basin below and exactly two above — is Q3, and it enters with every one of GG-P2-N3's declared conditions. Part IV states them.

13.3 What would count as a refutation

The ground-state account is sharper than the bookkeeping account in one observable respect: it forbids electron decay *absolutely*, including through any hypothetical charge-violating channel that bookkeeping cannot address (a charge-violating decay would falsify the SM argument's premise but not its logic; it would falsify Theorem 13.1 outright). Every improvement of the Borexino bound is therefore a direct test, and any observed decay, in any channel, kills this paper (Part VIII, F1).

Two of the six questions are now one statement about one minimum. After all, "nothing can be lower" is simultaneously the reason every copy is alike and the reason every copy endures — the first time in this paper, but not the last, that two of the century's questions collapse into a single sentence.

14 Part III in plain English: why every electron is identical, and why none has ever decayed

Two of the six questions turn out to be one question, and this Part is where they meet.

Quantum field theory already explains why electrons are alike: they are excitations of a single field, and ripples on one pond cannot disagree about what water is. That answer is correct, and the Part states it at full strength before adding anything to it. What it does not explain is the *content* of the likeness — why this field, carrying this mass and this charge rather than any other. Nor does it explain stability: nothing in the field picture forbids the electron from decaying, it simply has nowhere to decay to given the particles that happen to exist.

The claim here is that both gaps close together if the electron is the deepest basin of a landscape the geometry fixes. Identity follows because there is one basin and one way to read it. Absolute stability follows because there is no gate out of the bottom. The two are not separate results that happen to agree; they are one statement about one object, and the derivations are written out in the appendix so that a reader can check they are not the same assumption counted twice.

Part IV
The Excited Copies

μ and τ as geometrically excited electrons; the ladder ends at three (Q3)

15 The ladder and its terminus

Q3 is the cleanest of the six questions historically: since the muon appeared unbidden in cosmic rays (Neddermeyer & Anderson, 1937) — and since the tau completed the pattern at SPEAR (Perl et al., 1975) — the copies have had no explanation of any kind in standard physics. "Who ordered that?" has stood for ninety years. In QFT the three charged leptons are three independent fields; nothing makes the heavier two "excited states" of anything, and nothing prefers three to seventeen. This paper neither derives the answer nor restates its proof: the dedicated derivation is the sister paper GG-P2-N3 (Arisaka, 2026, P2-N3), and the division of labor is deliberate — GG-P2-N3 owns *why three*; the present paper owns *why the terminus is what it is*. This Part imports the result with its complete conditioning, because Q2 and Q3 are logically entangled: the stability of the electron is the statement that the ladder *ends*, and the count of the ladder is the statement of *where*.

The imported picture, in five sentences. The three generations are the three critical points of one GFF Morse landscape on the family-projector stratum $\mathbb{C}P^2$, organized as a GRIP-In cascade chain

$$\underbrace{[\,\mathrm{ind}=4\,]}_{\tau;\ \text{depth } 0} \xrightarrow{S=2\pi} \underbrace{[\,\mathrm{ind}=2\,]}_{\mu;\ \text{depth } 1} \xrightarrow{S=\pi} \underbrace{[\,\mathrm{ind}=0\,]}_{e;\ \text{depth } 2\ (\mathsf{GGA})} \tag{7}$$

(Arisaka, 2026, A9-SM, its labeled section `sec:lepton-cascade-depth`; Arisaka, 2026, P2-N3, §9). All three are genuine Geometric Attractors — index-0 minima of their depth-n effective landscapes, which is why m_τ and m_μ are sharply measurable — but only the electron's basin is the ground state. The masses are basin levels, produced by the same codebook as Eq. (3) at depths 0 and 1; the lifetimes are ordered by basin depth, with each non-ground generation exiting through its GSSB gate at Bogomolnyi toll 2π (then π); and the entire observed $\tau \to \mu \to e$ chain is a single GRIP-In descent, implemented physically by the weak interaction first written down by Fermi (Fermi, 1934) — the unique flavor-connecting channel of the boundary gauge group (Arisaka, 2026, A9-SM, the weak-as-GRIP-In doctrine). "Geometrically excited states of the electron" is thus not a metaphor: μ and τ occupy higher basins of the *same* landscape whose ground state is the electron, exactly as an excited atom occupies a higher level of the same Hamiltonian.

Physics intuition. The gate-and-toll picture is Gamow's alpha-decay mechanism lifted from a potential in space to a landscape of structure. In alpha decay the rate carries $e^{-2\int |p|\,dr/\hbar}$ — an action in an exponent; here each GSSB gate carries a Bogomolnyi action toll (2π, then π), and the cascade rates carry the corresponding e^{-S} suppressions, combined with phase-space factors exactly as nuclear lifetime systematics combine barrier penetrability with phase space (the quantitative accounting, including why phase space dominates the τ–μ lifetime ratio, is GG-P2-N3's §9.4). The familiar tunneling grammar — actions in exponents, tolls at passes, lifetimes ordered by what stands between a state and its destination — transfers whole.

Figure 6 draws the whole story in one picture; **Figure 7**, reproduced from GG-A9-SM, states the same chain as a Morse diagram — the figure that first drew, in the cohort, why exactly (e, μ, τ); and Table 2 records the assignment quantitatively. The reader who keeps these two figures has Parts III and IV of this paper. Figure 8 then places the same three generations on the cosmic descent — the energy-and-time axis running from the seam through TeV-scale leptogenesis to the electron, with the neutrino seesaw floor below.

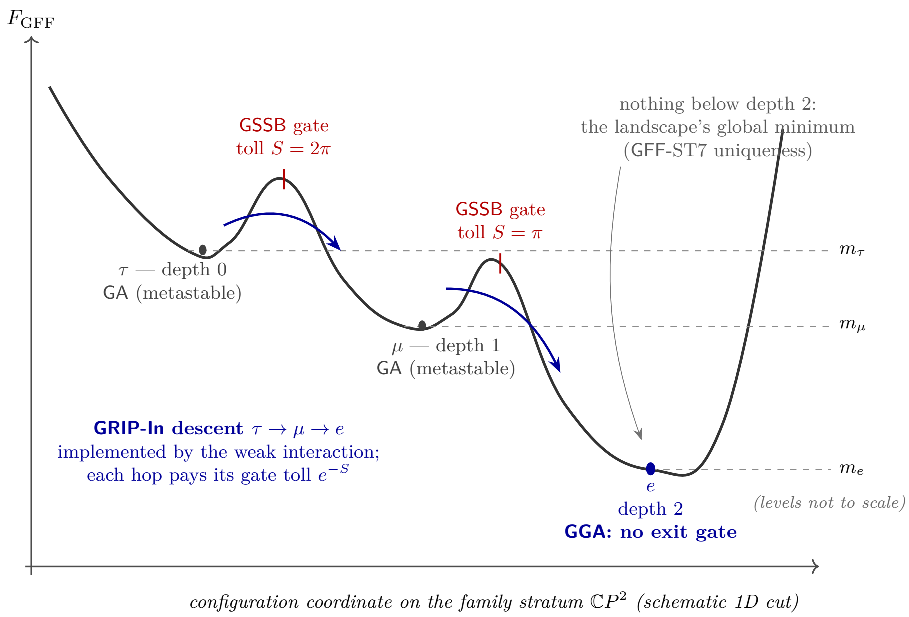

Figure 6: The charged-lepton landscape in one picture: a schematic one-dimensional cut through the GFF Morse landscape on the family stratum $\mathbb{C}P^2$. The three generations are the three basins; their floors are the masses (levels schematic, not to scale); the two GSSB gates carry the Bogomolnyi tolls $S = 2\pi$ and $S = \pi$; and the observed $\tau \to \mu \to e$ weak-decay chain is a single GRIP-In descent that pays both tolls and halts in the unique deepest basin — the GGA, which has no exit gate. Identity (one deepest basin), stability (no gate out of it), the excited copies (the two way stations), and the decay hierarchy (tolls in exponents) are all visible in this one drawing; pointlikeness is the statement that the horizontal axis is not a direction of space.

16 The conditioning, verbatim

The charter of this paper requires GG-P2-N3's fences to travel with every import, at every level including the abstract. They are restated here without dilution.

1. **Lower bound (L1) — conditional on an empirical input.** $N \geq 3$ follows from the

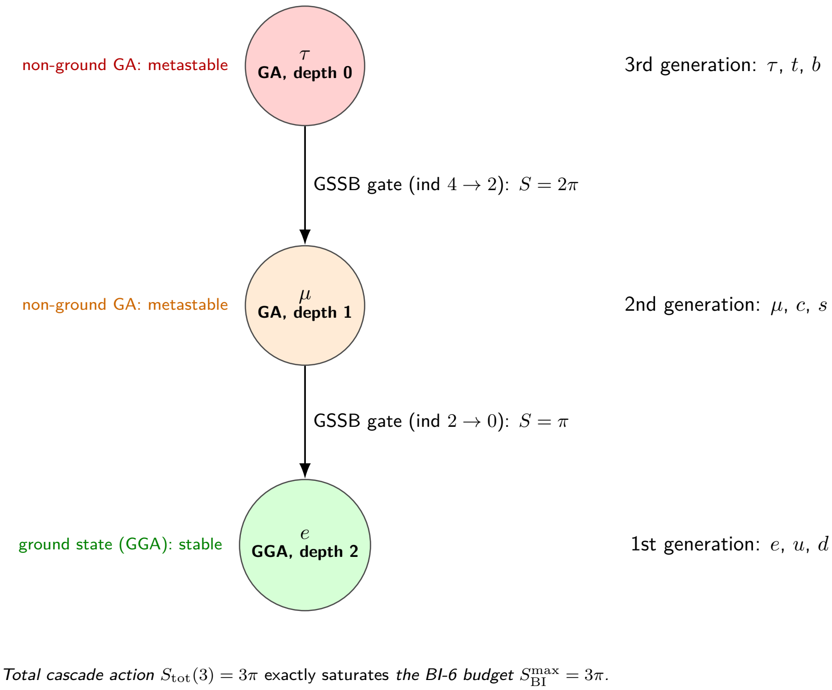

Figure 7: The GRIP cascade on the family-projector moduli $\Sigma_{\text{fam}} = \mathbb{C}P^{N-1} = \mathbb{C}P^2$ at $N = 3$, reproduced from GG-A9-SM (Arisaka, 2026, A9-SM) in the ground-state (GGA) reading. The Morse skeleton of the GFF height function keeps its three critical points (indices 4, 2, 0) and Bogomolnyi actions $S_{[2k]\to[2(k-1)]} = \pi k$ (Witten, 1982), accumulating to $S_{\text{tot}}(3) = 3\pi$ and exactly saturating the BI-6 budget — the three-leg count of GG-P2-N3, imported here with its conditioning (§16). What the figure states precisely is the particle identification: all three generations are genuine Geometric Attractors — index-0 basins of their depth-n effective landscapes, which is why m_τ and m_μ are sharply measurable — but only the depth-2 basin is the *Ground* Geometric Attractor. The non-ground GA's relax toward it ($\tau \to \mu \to e$); the GGA never decays. The index-4 and index-2 critical points are the GSSB gates the descent crosses, not the particles; the two arrows are steps of a single GRIP-In descent on a fixed landscape, and the GGA is where GRIP-In halts.

observed non-vanishing of CP violation (the Jarlskog invariant (Jarlskog, 1985) $J_{\text{CKM}} \neq 0$, CP violation having been observed since Christenson et al., 1964): with fewer than three families a unitary mixing matrix has no physical CP phase. Status: theorem given the empirical input.

2. **Upper bound (L2) — conditional on the coupling clause and the integrality theorem L-INT (residue R-INT).** The bound $N \leq 3$ consumes the capacity theorem T-N3-6 of Arisaka (2026, P2-N3) ($\text{Cap}(N) = \pi N$, saturating at 3π; its Appendix C records the two viable formulations), which is derived there from the family stratum's quantum geometry — Berry transport and the Fubini–Study package, forced at the Born theorem's own grade by its adiabatic theorems T-AD-1–T-AD-3 — conditional on the coupling clause (its Axiom AX-B) and the integrality theorem L-INT, whose single topological residue R-INT "is topological bookkeeping on a specific manifold, of the same kind as checking orientability, not a conceptual gap" — GG-P2-N3's own words, adopted verbatim; its Appendix H discharges that residue on the benchmark background. The two would-be hypotheses of the natural axiomatization are dissolved there: H_1 is closed in the negative (the rigidity lemma: every functorial descent

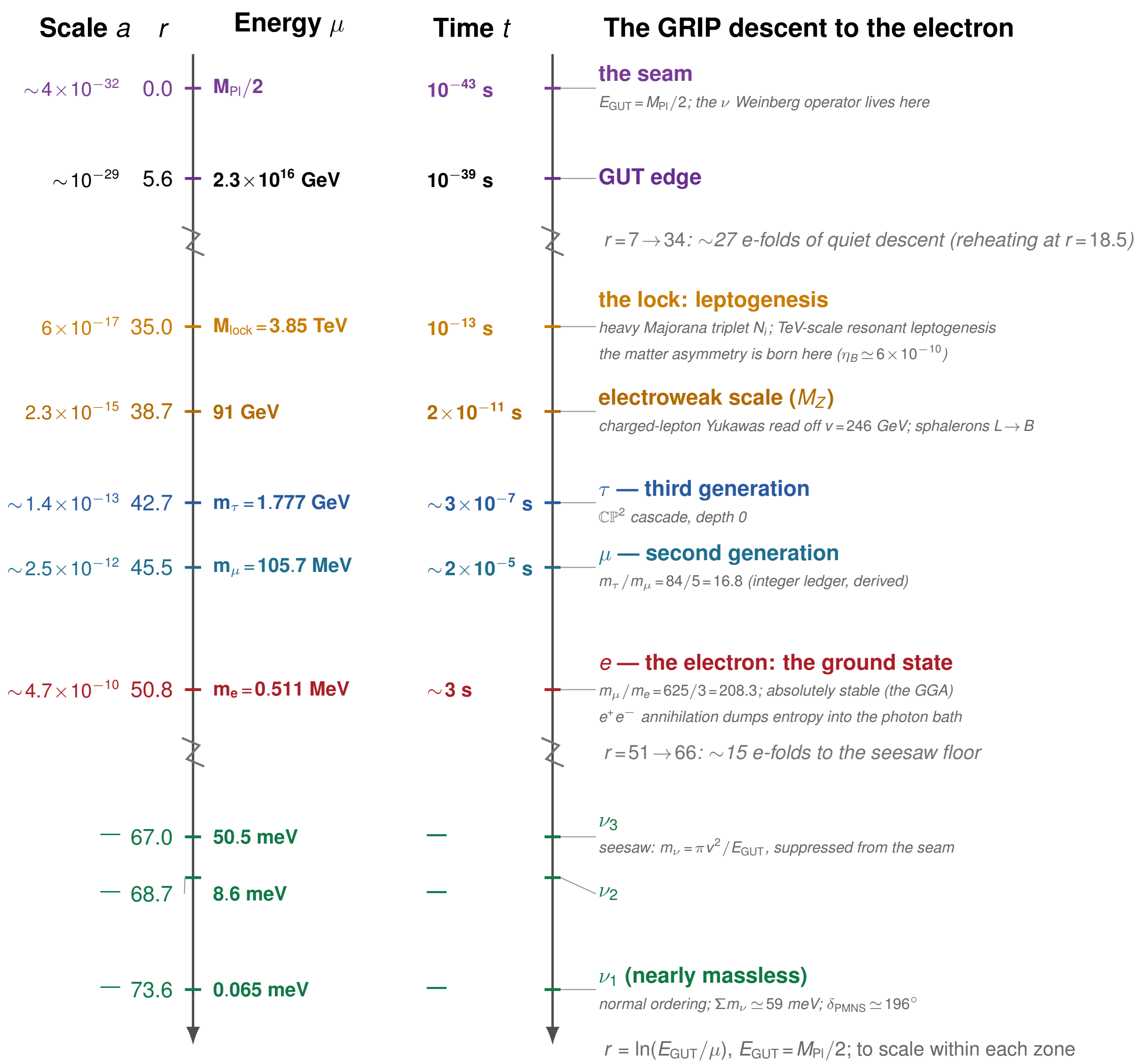

Figure 8: The three charged generations and the neutrino sector placed on the GRIP-In descent axis $r = \ln(E_{\rm seam}/\mu)$ ($E_{\rm seam} = M_{\rm Pl}/2$, the lock at $r = K = 35$), read down four quantities: the cosmic scale factor a, the depth r, the energy μ, and the time t. From the seam — where the neutrino Weinberg operator is anchored — the descent passes the lock, the heavy Majorana triplet and TeV-scale resonant leptogenesis where the matter asymmetry $\eta_B \simeq 6 \times 10^{-10}$ is born (GG-A10-Cosmos, GG-A11-Origin), and then the electroweak scale, where the charged-lepton Yukawas are read off $v = 246$ GeV. The three generations land as basin levels of the one $\mathbb{C}P^2$ cascade: τ (depth 0), μ (depth 1), and the electron (depth 2, the GGA) — absolutely stable, the ground state of the ladder and the terminus of this paper. The integer-ledger ratios $m_\tau/m_\mu = 84/5$ and $m_\mu/m_e = 625/3$ are the derived content (GG-A9-SM); the absolute masses are the codebook readout at their stated grade. Below the electron lies the seesaw floor, $m_\nu = \pi v^2/E_{\rm GUT}$ suppressed from the seam, giving $(m_1, m_2, m_3) \simeq (0.065,\ 8.6,\ 50.5)$ meV in normal ordering with $\delta_{\rm PMNS} \simeq 196°$. Drawn to scale within each zone; the two axis breaks compress the quiet descent and the gap to the seesaw floor.

Table 2: The lepton cascade assignment with empirical values (PDG 2024 Particle Data Group, 2024; lifetime bound Borexino Collaboration, 2015). Depths, indices, and tolls from the imported GG-P2-N3/GG-A9-SM chain (Eq. 7); the toll column is the exit gate *out of* the basin. Masses and lifetimes are measured; the mapping of basins to particles is the imported theorem; the toll values inherit the Part IV conditioning.

Particle	Depth	Morse index	Exit toll	Mass [MeV]	Lifetime
τ	0	4	$S = 2\pi$	1776.93(9)	$2.903(5) \times 10^{-13}$ s
μ	1	2	$S = \pi$	105.6583755(23)	$2.1969811(22) \times 10^{-6}$ s
e	2	0 (GGA)	**none** (no gate)	0.51099895069(16)	stable; $\tau_e > 6.6 \times 10^{28}$ yr

of the bulk data vanishes), and H_2's salvageable content is L-INT, now the derived theorem with residue R-INT. The same budget value is consumed, not derived, by GG-A6-GRIP's cascade-closure theorem T4.1, whose open problem M10 records the missing derivation.

3. **Reachability reading — interpretation, not proof.** The dynamical reading of $N < 4$ — a fourth family's relaxation road would cost $\pi N(N-1)/2 > \pi N$, leaving its ground state dynamically unreachable — "inherits the conjectural status of the budget and adds none of its own rigor" (Arisaka, 2026, P2-N3, §9.5, verbatim). We use it in this paper exactly as GG-P2-N3 licenses: as the physical interpretation that converts "why this budget?" into "why must every family be reachable?", to which GFF-ST7 is the cohort's declared answer.

4. **Empirical anchors.** The lepton-counting input $N_\nu = 3$ from the Z resonance (ALEPH et al., 2006), and the codebook's four-significant-figure agreement on the mass ratios ($m_\tau/m_\mu = 16.817$, $m_\mu/m_e = 206.768$), are empirical validations, not premises of the geometry.

Figure 9 draws the budget accounting these fences guard, specialized to the lepton stratum.

For the present paper the load-bearing consequence is modest and worth stating exactly: *Q2's "no exit gate" (Theorem 13.1) does not depend on the upper bound $N \leq 3$.* Even if a fourth family were discovered — killing GG-P2-N3 and falsifier F3 below — the electron would remain the GGA of its stratum unless the new state were charged and *lighter*. What the budget machinery adds is the conjunction: the same finite resource that stops the ladder at three guarantees that the terminus is reachable and final — the universe not only has a ground floor, it can always get there. That sentence is the new content of this Part, and it carries the conjectural status of ingredient 2 above.

After all, the muon was never an intruder. It is the electron, one basin up — and the ninety-year-old question "who ordered that?" dissolves into the older and better question of why a landscape should have exactly three floors, which is the sister paper's to answer.

17 The descent rate: the muon lifetime as a GRIP-In observable

Part IV has so far read the charged-lepton stratum *statically*: the three generations are the basins of the GFF Morse landscape, their floors are the masses, and the two GSSB gates between them carry the Bogomolnyi tolls $S_{[4]\to[2]} = 2\pi$ and $S_{[2]\to[0]} = \pi$ (**Figure 9**). But a basin has a second, dynamical readout. A non-ground attractor does not merely sit at its floor; it *falls*, across

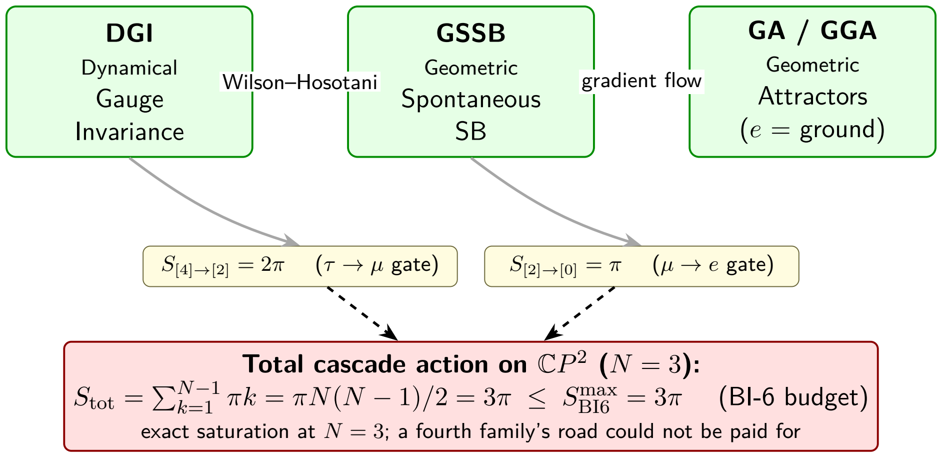

Figure 9: The cascade-with-budget accounting, adapted from GG-A6-GRIP (Arisaka, 2026, A6-GRIP) and specialized to the charged-lepton stratum at $N = 3$. Each GSSB gate costs its Bogomolnyi toll (2π for $\tau \to \mu$, π for $\mu \to e$); the chain sum $S_{\text{tot}} = \pi N(N-1)/2$ exactly saturates the BI-6 budget $S_{\text{BI6}}^{\max} = 3\pi$ at $N = 3$. The budget value is the capacity theorem T-N3-6 of GG-P2-N3 (Arisaka, 2026, P2-N3) — derived there from the stratum's quantum geometry, conditional on the coupling clause and the integrality theorem L-INT (residue R-INT), and meeting the N-independence demand recorded as GG-A6-GRIP's open problem M10 — and every use of this figure inherits that conditioning verbatim (§16).

its gate, toward the GGA. The rate of that fall is an observable, and for the muon it is the lifetime, $\tau_\mu \approx 2.2\ \mu$s. This section shows that the lifetime is as much a GRIP output as the mass: the mass is the floor of the basin, and the lifetime is the rate at which the basin is vacated across its GSSB gate.

17.1 Two readings of one basin: the floor and the gate

The runtime layer of GRIP already carries this dynamical readout. The seventh structure theorem of the pipeline (GG-A6-GRIP (Arisaka, 2026, A6-GRIP), **GRIP-ST7**) states that the generation decay-width ladder of unstable boundary states is the direct projection of the cumulative cascade action: a state that must cross a gate of toll $S = \pi k$ to leave its basin acquires a width whose leading behavior tracks $e^{-\pi k}$. Mass and width are thus the two faces of the same critical point — the depth of the floor and the toll of the gate.

The terminus makes the duality sharp. The electron is the GGA: the unique deepest basin, the one critical point with *no* exit gate (§15, Theorem 13.1). With no gate to cross there is no descent, no width, and no decay: $\Gamma_e = 0$, $\tau_e = \infty$. Absolute electron stability, derived in Q2 as a statement about the *form* of the landscape, is therefore identically a statement about the *rate* on that landscape — the gate-crossing rate evaluated at zero gates. The muon, one basin up, has exactly one gate ($S_{[2]\to[0]} = \pi$); it falls, and the finiteness of its lifetime is precisely the dynamical signature of being a non-ground GA.

17.2 The weak interaction as the implementer of the descent

GRIP-In fixes *that* the muon descends and *across which* gate; the weak interaction is what physically *carries out* the crossing — Nature's implementer on the matter strata (**Figure 7**). The gate transition $\mu^- \to e^-\bar{\nu}_e\nu_\mu$ is the charged-current weak vertex evaluated on the symmetry-broken ($v \neq 0$) branch selected at the GSSB stage. Its strength is not a fitted constant but the geometric weak scale: the Fermi coupling is

$$\frac{G_F}{\sqrt{2}} = \frac{1}{2v^2}, \qquad \text{i.e.} \qquad G_F = \frac{1}{\sqrt{2}\,v^2}, \tag{8}$$

where v is the boundary vacuum amplitude fixed by GG-A9-SM's Wilson–Hosotani theorem (Arisaka, 2026, A9-SM) — itself the readout of the one electroweak GRIP-Out event that built this landscape in the first place. The coupling that sets the descent rate is therefore inherited from the same geometry that dug the basins.

17.3 The descent rate in closed form

Treating the gate-crossing as a single inclusive jump into the electron–neutrino continuum and evaluating the golden-rule rate with the charged-current vertex gives the textbook leading-order width, now read as a GRIP quantity,

$$\Gamma_\mu^{(0)} = \frac{G_F^2\, m_\mu^5}{192\pi^3} = \frac{m_\mu^5}{384\pi^3\, v^4}. \tag{9}$$

Each factor has a cascade meaning: G_F^2 is the squared geometric coupling of the gate; m_μ^5 is the phase-space measure of the descent — the basin-floor gap raised to the fifth power by the three-body leptonic final state; and $192\pi^3$ is the dimensionless normalization of that final state. The lifetime is $\tau_\mu = \Gamma_\mu^{-1}$.

The number is verified. With the empirical inputs the leading-order form (9) gives $\tau_\mu^{(0)} = 2.187\ \mu$s; restoring the exact phase-space factor $f(m_e^2/m_\mu^2) = 0.99981$ and the leading QED radiative correction $1 + \frac{\alpha}{2\pi}\left(\frac{25}{4} - \pi^2\right) = 1 - 4.2 \times 10^{-3}$ yields $\tau_\mu = 2.19699\ \mu$s, against the measured $2.1969811(22)\ \mu$s (Particle Data Group, 2024) — agreement at the part-per-million level. Inserting the geometric scale $v = 246.22$ GeV in (8) reproduces G_F, and hence τ_μ, identically: the lifetime is anchored by a geometric weak scale, not by a fitted weak constant.

17.4 The descent as a CPTP semigroup

Rigorously, the descent is an open-system process: the boundary observer holds the one-muon sector and traces over the electron and neutrinos. Under the constitutional open-system rule (GDOS POS-4; GG-A6-GRIP) the reduced evolution is a CPTP semigroup, and for a single dominant gate it is generated by one Lindblad jump operator

$$\mathcal{L}_\mu(\rho) = -i[H_{\text{eff}}, \rho] + L_\mu \rho L_\mu^\dagger - \tfrac{1}{2}\{L_\mu^\dagger L_\mu, \rho\}, \qquad L_\mu = \sqrt{\Gamma_\mu}\,|e{\downarrow}\rangle\langle\mu|, \tag{10}$$

so that the surviving-muon population obeys $\rho_{\mu\mu}(t) = \rho_{\mu\mu}(0)\, e^{-\Gamma_\mu t}$. The exponential law is the runtime *form* of a non-ground GA relaxing across its gate. The contrast with the GGA is exact and instructive: the electron sector carries *no* jump operator, because it has no gate; its reduced generator is purely unitary, $\Gamma_e = 0$, $\tau_e = \infty$. The single generator (10), evaluated at one gate versus zero gates, contains both the muon's lifetime and the electron's absolute stability. Decay and permanence are not two phenomena here but one GRIP statement read at two depths of the same cascade.

17.5 DGI $\to$ GSSB $\to$ GA staging, and a correction of one tempting misreading

The lifetime sits in the runtime grammar exactly as the mass does. *DGI*: the reduced generator (10) inherits the gauge covariance of the parent charged current, so Γ_μ is a gauge-covariant scalar — no legal change of electroweak basis can alter it. *GSSB*: the gate is the Bogomolnyi toll $S_{[2]\to[0]} = \pi$, realized physically by the weak vertex on the broken branch. *GA/GGA*: the descent runs from the muon GA to the electron GGA, the exponential law is its signature, and the GGA is its terminus.

One misreading is worth closing off, because it is natural and wrong. It is tempting to call the muon "a GA whose attractor is its own decay law." In the GRIP vocabulary the attractors are the *basins*, not the laws, and the muon is a *non-ground* one: its lifetime is not the muon attracting anything but the rate at which it is drawn toward the true attractor of the stratum, the electron GGA. The decay law is the shadow of the descent, not an attractor in its own right.

17.6 Status: a derived reading on a conditioned number

Honesty requires separating the reading from the number. The closed form (9) rests on two inputs of different provenance in the GG-A9-SM codebook (Arisaka, 2026, A9-SM): the weak scale v (equivalently G_F) is **Derived (conditional)**, while the muon mass m_μ is **Asserted** — its cascade depth is the open lemma. Since $\tau_\mu \propto 1/(G_F^2 m_\mu^5)$, the *numerical* lifetime inherits the Asserted status of the muon-mass depth: it is a structurally expressed GRIP-In descent rate, derived *modulo* that one Asserted depth, and is not advanced as a parameter-free postdiction of 2.2 μs. What is new and *unconditional* is the reading: the lifetime is the gate-crossing rate of the cascade, the dynamical dual of the mass. The local perturbative rate and its radiative corrections are the ordinary ones; GRIP changes their origin (the coupling is geometric) and their meaning (a runtime descent rate), not the calculation.

Proposition 17.1 (Muon lifetime as a GRIP-In descent rate)**.** *On the charged-lepton stratum $\Sigma_{\text{fam}} = \mathbb{C}P^2$ the non-ground geometric attractor μ relaxes to the ground attractor e by a single GRIP-In descent across the GSSB gate $S_{[2]\to[0]} = \pi$, implemented by the weak charged current with geometric coupling $G_F = 1/(\sqrt{2}\,v^2)$. The reduced one-muon sector is a CPTP semigroup with jump operator $L_\mu = \sqrt{\Gamma_\mu}\,|e{\downarrow}\rangle\langle\mu|$ and survival $\rho_{\mu\mu}(t) = e^{-\Gamma_\mu t}$, where*

$$\Gamma_\mu = \frac{G_F^2 m_\mu^5}{192\pi^3} = \frac{m_\mu^5}{384\pi^3 v^4}, \qquad \tau_\mu = \Gamma_\mu^{-1} = 2.197\ \mu s$$

(leading order 2.187 μs; the exact phase space and leading radiative correction give 2.19699 μs, the measured value to the part-per-million). The ground attractor e has no exit gate, so $\Gamma_e = 0$ and $\tau_e = \infty$: absolute electron stability (Theorem 13.1) is the same statement evaluated at zero gates. Conditioning: v (hence G_F) is Derived (conditional) and m_μ is Asserted in GG-A9-SM, so the numerical lifetime is derived modulo the Asserted μ depth, while the reading of τ_μ as the cascade's

gate-crossing rate is unconditional.

The ladder of Part IV is therefore two ladders at once. Read by floors it is the mass ladder $m_\tau > m_\mu > m_e$; read by gates it is the lifetime ladder, the τ falling fastest, the μ more slowly, and the electron not at all. The same three basins, the same two tolls, the same single GRIP-In descent — seen once as where the generations sit, and once as how quickly they give way to the one that stays. A static observable and a dynamical observable, drawn from one cascade: the universality of GRIP is that the mass and the lifetime are not two inputs but two readings of the same geometry.

17.7 Summary: what the muon's mass and lifetime, together, tell us

It is worth stepping back from the equations and saying, in plain terms, what has been done here — because the lesson matters well beyond particle physics, and a reader arriving at this program from biology or the study of the mind (GG-A11-Origin (Arisaka, 2026, A11-Origin)) will recognize the grammar.

Two facts about the muon are usually written into the rulebook of physics by hand: how heavy it is, and how long it lives (about two-millionths of a second). The picture in this paper is that they are not two facts but one. Imagine a landscape of hills and valleys. Every kind of particle is a valley — a place the geometry permits a stable pattern to sit. The electron is the *deepest* valley on its sheet: there is nowhere lower to roll, so it never decays, and it is exactly this that we proved as its eternal stability. The muon is a *higher* valley on the same sheet. It cannot stay; it rolls down, across the ridge between the valleys, and ends as the electron.

In that picture the muon's **mass** is simply how deep its valley lies, and its **lifetime** is how quickly it rolls across the ridge and out. Depth and crossing-rate — two readings of one and the same valley. The mass formula and the lifetime formula (the 2.197-microsecond number, reproduced to a part in a million) are not independent assumptions bolted together; they are the static and the dynamic face of a single geometric object. Obtaining *both* from one structure, rather than measuring two unrelated constants, is the economy that distinguishes the GDOS/GRIP reading from the textbook one — which it otherwise leaves entirely intact.

This collapses two questions long treated as separate. *What is a particle?* (its identity, its mass) and *how long does it last?* (its stability, its lifetime) become the same question asked twice: once about where a valley sits, and once about whether it has a way out. The electron's permanence and the muon's mortality are then literally the same statement, evaluated with *no* exit gate versus *one*. No competing framework reads a particle's existence and its lifespan off a single geometry; that is the uniqueness of the construction.

For the life scientist the point is not the muon but the *grammar*, which is the one GG-A11-Origin carries all the way up. Valleys are attractors — the stable forms the world settles into (GA), with one deepest, the ground form (GGA). Ridges are gates — the thresholds a state must cross to change. Rolling downhill is GRIP-In, relaxation toward a stable form on a fixed landscape. And the rare events that re-carve the landscape itself, opening valleys that did not exist before, are GRIP-Out — the electroweak vacuum here; the origin of life, of the cell, of the conscious episode there. The muon is the cleanest specimen of this grammar there is: a single elementary particle whose very existence and whose lifespan are both nothing but geometry. If the bookkeeping is this exact for the simplest case, the claim of GG-A11-Origin is that the same bookkeeping — attractors, gates, descents, and landscape-remaking events — runs through atoms and molecules to cells and minds, each a higher and richer attractor with its own gates and its own characteristic times. The muon is the Rosetta stone: small enough to solve exactly, and written in the same language as everything above it.

One honesty note carries over from §17.6. How deep the muon's valley lies — its mass — is, in the present codebook, still an assumed input awaiting its closing lemma, so the precise lifetime number inherits that one assumption. What is already secure, and what this Part adds, is the reading itself: that a particle's mass and its lifetime are one geometric object seen twice. That reading does not wait on the open lemma.

18 Part IV in plain English: the muon, the tau, and what this paper does and does not claim

"Who ordered that?" has stood since 1937. Standard physics treats the three charged leptons as three independent fields: nothing makes the heavier two excited versions of anything, and nothing prefers three to seventeen.

This Part is careful about ownership, and the care is not decorative. The derivation that there are exactly three lives in the sister paper, not here, and it is imported with its conditioning stated in full rather than quoted as a bare result. What this paper owns is the other half — why the ladder ends where it does, and why the bottom rung is the particle we are made of.

The two halves are entangled, which is why the import has to be exact. Absolute stability is a statement about there being nothing below the electron, and that is only meaningful if the ladder is finite and its structure is known. A reader who wants the family count proved should read the sister paper. A reader who wants to know what the count costs, and what would falsify it, will find that here — including the muon lifetime, computed rather than fitted, carrying the conditioning that computation inherits.

Part V
The Origin of Positrons

The sixth question: Dirac's reluctant twin and Anderson's photograph; the origin of antiparticles imported at theorem grade from the CPT companion; and the positron as the conjugate readout of the electron's one basin — one object, two orientations of reading it

19 The sixth question, and why it waited differently

Five of this paper's questions share a biography: asked early, filed away, unanswered for a century. The sixth has the opposite biography, and the difference is instructive: it was *answered* before anyone had properly asked it — and the answer was so spectacular that physics mistook it for an explanation for ninety years.

The story is the most famous consistency crisis in the subject. In 1928 Dirac wrote down the relativistic wave equation the electron had forced into existence (Dirac, 1928), and the equation immediately returned more than it was asked for: alongside the positive-energy electron states came a mirror family of negative-energy states that could be neither discarded (the equation's completeness forbids it) nor tolerated (an electron with states of arbitrarily negative energy below it would radiate its way down forever — no atom would be stable). Dirac's first instinct was to hide the shadow in a filled sea and identify its holes with the proton, the only positive particle then known; the mass refused to cooperate. In 1931 he conceded what the equation had been saying all along: the holes are a *new* particle, "a new kind of particle, unknown to experimental physics, having the same mass and opposite charge to an electron" (Dirac, 1931). The following year Carl Anderson, photographing cosmic-ray tracks in a magnetized cloud chamber and initially unaware of Dirac's prediction, recorded a particle bending the wrong way with the electron's mass (Anderson, 1933). Theory had predicted a twin from consistency alone; nature produced it within the year.

Here is the mis-filing. What the episode established is that the *formalism* demands the twin: relativistic quantum theory cannot be written without antiparticles, and quantum field theory subsequently made the demand systematic — every charged field creates its particle and annihilates its antiparticle, one operator, both signs. That is a genuine and permanent achievement, credited here without reservation. But "the equation predicts it" names a mystery rather than dissolving it. *Why* does consistency want a twin? What, in the furniture of the world rather than in the algebra of a formalism, *is* the positron? And for this paper the question has a sharper, internal form, stated as Objection 8: Part III proved the electron is the *unique* ground state of its stratum — one basin, no second place to stand. A unique ground state that did not accommodate the antiparticle would be refuted by every PET scan performed today. Answering that in full needs the origin of antiparticles at theorem grade, below quantization, and the cohort's CPT companion GG-P5-CPT (Arisaka, 2026, P5-CPT) supplies exactly that, in the real geometry of the bulk; the debt is registered by name as D-P3-4. On that import the question can be met with a chapter rather than a fence. That is this Part: the sixth question, asked at last in the form the century skipped, and answered with the imports priced.

The question, precisely. **Q6 (The twin):** why does the electron have an antiparticle — a twin of exactly equal mass and exactly opposite charge — and what is the positron, if the electron is the unique ground state of its stratum?

20 The standard answer, and its edge

As with Q1, Q2, and Q5, standard physics has real content here, and the thesis of this paper survives only alongside the credit.

What is genuinely explained. Two things. First, *necessity at the level of the formalism*: one cannot write a relativistic, causal, positive-energy quantum theory of a charged field without antiparticle solutions; the Feynman–Stückelberg identification organizes them, and quantum field theory builds them into the operator content from the start (Weinberg, 1995). Second, *the pairing constraints*: the CPT theorem — provable from Lorentz invariance, locality, and hermiticity — forces particle and antiparticle to share mass, total width, and magnitude of charge and magnetic moment. These are the two load-bearing walls of the standard account, and both stand.

Where the edge is. Ask three childishly direct questions and the account goes quiet, in a specific and diagnosable way — GG-P5-CPT sharpens the diagnosis as "three questions wearing one coat." *(i) Why does consistency want a twin at all?* The theorems say that relativistic quantum theory without antiparticles is inconsistent; they do not say what feature of the world the inconsistency is protecting. *(ii) Where does the twin first exist?* In the standard account the antiparticle is born in the quantization procedure — it appears when operators are assigned to Fourier components — which leaves the question "did the twin exist before we quantized?" sounding meaningless rather than answered. *(iii) What is the relation between the twin and the original?* The CPT theorem *constrains the pair* — it is Depth-2 knowledge, in the grading GG-P5-CPT uses: given two objects, their properties must match. It cannot say whether there are really two objects at all. The equality of the electron and positron masses is, in the standard account, an exact relation between two distinct fields, enforced by a symmetry — a fact that should strike the reader as one coincidence deeper than it needs to be, exactly as two identical electrons once did (Q1).

The sixth question therefore has the same shape as the other five: a formalism that handles the fact perfectly while declining to say what the fact is. And as with the other five, the missing layer turns out to be geometric.

21 The GG-Theory answer, imported at theorem grade

The derivation belongs to GG-P5-CPT, where it occupies a full Part — "The Origin of Antiparticles" — and it is the sibling of the origin-of-i treatment in Arisaka (2026, P4-Real); this section imports its three theorems in digest, at the level this paper's argument needs, with the full proofs cited rather than reproduced (the division of labor this cohort uses throughout; the reader who wants the monograph treatment should read the companion's Part directly). The derivation lives at a level most treatments never visit: *below quantization*, in the real geometry of the bulk's solution spaces — which is precisely why it can answer question (ii) above, where the twin first exists.

The two real structures. Recall the two non-spatial directions of the bulk (Part II): the compact phase circle S^1_θ and, on the 4D boundary, causal time. Each, independently, equips the *real* solution space of a charged bulk field with a complex structure — a real operator squaring to $-\mathbf{1}$:

The circle (T-P5-A). On each charge-n sector, the charge-normalized circle generator is a complex structure: rotating the compact phase by a quarter turn *is* multiplication by i, and complex conjugation is orientation reversal of the circle, $\theta \mapsto -\theta$. It is the unique such structure commuting with the circle action — up to sign. On neutral (weight-zero) sectors it acts as zero: *the circle can only complexify what it moves.*

The clock (T-P5-B). On the same real solution space, the polar phase of the time-translation generator is a complex structure — the positive-frequency splitting of the field, selected uniquely by the positivity clause of the cohort's axioms. This is the i of the state space: the one quantization needs.

The handshake (T-P5-C). Two independently forced structures on one space must either agree or clash. The computation that decides it is two lines, and worth performing once. An on-shell mode of charge n and energy $E > 0$ is the real oscillation with total dial angle $n\theta - Et$, i.e. $u_+ = \cos(n\theta - Et)$. The circle turns the fiber: $\cos \mapsto -\sin$. The clock advances the phase a quarter period: $\cos \mapsto -\sin$. *They agree* — but only on the pairing that puts charge $+n$ *and* charge $-n$ both at positive frequency; on the opposite pairing they anti-agree. The Feynman–Stückelberg pairing is therefore not a convention of quantization but the unique orientation under which two independently forced real structures act as one complex structure on shell. In the companion's summary: *the existence of antiparticles is the consistency condition between the sixth dimension and causal time.* That answers (i). And because the whole argument runs on real solution spaces, before any operator is introduced, it answers (ii): the twins exist in the bulk, as real geometric content, prior to quantization — the descent to the boundary only relabels them. For fermions, the further factorization theorem (T-P5-C2) makes the charge flip *definitional*: the conjugate readout is the reversed winding, not a second postulate.

Physics intuition. A charged mode is a single real wave carrying one dial angle, $n\theta - Et$: so much circle, so much clock. There are exactly two ways to read a dial — clockwise and counterclockwise — and a reader who reverses *both* the circle and the clock sees the same wave with the labels flipped: opposite winding, same energy. The twin is not a second wave; it is the second way of reading the first one. Nature did not manufacture antimatter to balance the books — the books were written in real ink, and every real oscillation admits two orientations of the same rotation. That is why the twin was *unavoidable* for Dirac: his equation was the first place the circle and the clock were forced to agree in public.

22 The positron: the same electron, read in the mirror

Now return the imported theorems to this paper's landscape, where the sixth question meets the first.

Part III established one basin: the electron is the unique GGA of the charged-lepton stratum — one deepest valley, one set of derived values, no second place for charged matter to rest. The handshake supplies the missing half of the picture: every reading of that basin comes in two orientations. The positron is *the conjugate readout of the same basin* — the same level of the same valley (hence exactly the electron's mass), read with the winding reversed (hence exactly the opposite charge, by T-P5-C2's factorization), with the spinor half of the statement carried by the quaternionic structure of Eq. (6) applied to the conjugate orientation (the remark of §12.3, now given its proper home). What the framework forbids — what Part III's uniqueness theorem actually says — is a second *basin*, not a second *orientation*. One object; two ways of reading it.

Three consequences repay attention; the first is the deepest.

Mass equality is trivial, not enforced. In the standard account, $m_{e^+} = m_{e^-}$ is an exact relation between two objects, policed by the CPT theorem: Depth-2 knowledge, a constraint on a pair. In the readout picture there is no pair to constrain — where there are not two things, nothing can differ. The most precisely verified equality in particle physics is exposed as the least surprising: it has the same status as the statement that a valley is as deep read clockwise as counterclockwise. The economy is identical to Q1's: identity was dissolved by counting objects correctly (one attractor, many readouts), and the twin dissolves the same way (one attractor, two orientations). *The sixth question collapses into the first.* Every electron is the same electron; the positron is the same electron, read in the mirror.

The charge flip is definitional. The positron does not *happen* to carry $+e$; the conjugate readout *means* the reversed winding, and charge is winding (Part III). Asking why the positron's charge is exactly opposite is asking why the reverse of a left turn is a right turn.

The daily-life anchor. Positron-emission tomography is conjugate-readout physics practiced in hospitals: a proton-rich nucleus converts, the emitted positron thermalizes within millimeters and meets an electron, and the pair annihilates into two back-to-back 511 keV photons — the basin level of Part III, read out twice with opposite orientations and returned to the field as pure energy. Every PET image is, in this paper's terms, a tomogram drawn in annihilation events of the one basin's two readings; the machine works *because* the twin is exact. (Wheeler's famous one-electron fancy — every electron and positron as one world-line zig-zagging through time — was, on this reading, a true instinct expressed one level too literally; the companion paper records the contact.)

Why, then, a matter world? If the twin is exact, why is the universe made of electrons rather than an even mix? That is the third of the three questions in the one coat, and it leaves the electron's scope: the cosmic preference for one orientation is the baryogenesis-and-leptogenesis chain, treated in the companion papers (Arisaka, 2026, P5-CPT; Arisaka, 2026, A10-Cosmos). This paper imports only the local statement: nothing about the boundary readout of the electron's basin prefers one orientation — the preference is cosmological history, not lepton structure.

23 Closed and fenced: the Q6 status

Per the discipline of §3, the sixth question's answer is priced line by line.

Table 3: The Q6 status table: what is imported at theorem grade, what is interpretive, and what remains owed. Tag vocabulary as in §3; the per-step registry rows are in Appendix B. The three columns separate what is carried in at theorem grade from what is a reading of it and what remains owed — Q6 being the question where those three are easiest to confuse with one another.

Statement	**Status**	**Source**
For every charged field, a twin of equal mass and opposite charge — forced, not chosen	THM (imported)	GG-P5-CPT T-P5-A, T-P5-B, T-P5-C
The twin exists in the real bulk, before quantization; the descent only relabels it	THM (imported)	GG-P5-CPT, same chain
For fermions the charge flip is definitional: conjugate readout = reversed winding	THM (imported)	GG-P5-CPT T-P5-C2
The positron is the conjugate readout of the *same* electron basin (no second basin)	INT (named)	this Part, §22; GG-P5-CPT's reading, adopted
Promotion of that reading to a proved corollary of the bulk spinor structure	OWED	D-P3-4 (§40), unchanged

What the fence does and does not cover. The *origin* of the twin is no longer owed: existence, bulk-level residence, mass equality, and the definitional charge flip are imported theorems. The open residue is exactly one step — proving, from the quaternionic spinor structure of Eq. (6) applied to the conjugate orientation, that every statement of Part III carries over verbatim to the reversed reading: same basin level, same absence of exit gates, spinor content conjugated and nothing else. That is D-P3-4, registered before this Part existed and deliberately left open by it: an honest chapter does not close its own fence by enthusiasm.

The falsifier face. The reading is exposed wherever the twins could differ. The current precision record: the electron–positron mass difference is bounded at $|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$ (90% C.L., from positronium spectroscopy Fee et al., 1993); the charge sum at $|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$ (Hughes & Deutch, 1992); and the g-factors agree at $(g_{e^+} - g_{e^-})/g = (-0.5 \pm 2.1) \times 10^{-12}$, from the Penning trap (Van Dyck et al., 1987) — among the sharpest null tests in physics. For the standard account these are tests of the CPT theorem; for this Part they are sharper than that: a *confirmed* asymmetry in any of them would falsify not merely a symmetry of the pair but the claim that there is no pair — the conjugate-readout reading dies first, before CPT does. The exposure is permanent, two-sided, and running in laboratories now: the sixth question's answer, like the other five, can be shot every day it stands.

After all, the century did not fail to answer the sixth question; it answered it so well, so fast, that no one noticed the answer was a description. The equation predicted the twin. It took the geometry to say what the twin is: the same electron, read the other way around.

24 Part V in plain English: the one question that was answered before it was asked

Five of these questions were asked early and then filed away. The sixth has the opposite history: it was answered in 1928, before anyone had properly asked it, and the answer was so spectacular that physics mistook it for an explanation for ninety years.

Dirac's equation returned more than it was asked for — a mirror family of states that could be neither discarded nor tolerated — and the resolution, that the mirror states are antiparticles, was confirmed by a photograph four years later. It is one of the great predictions in the subject and nothing here diminishes it.

But "the equation requires it" is a consistency argument, not a derivation. It establishes that the twin must exist; it does not say why the mathematics had a twin in it to begin with. This Part offers the missing half: the positron as the conjugate readout of the same basin, forced by the same geometry that fixes the electron. The status table at the end of the Part is unusually explicit about which parts of that are theorem-grade, which are readings of a theorem, and which are still owed — because Q6 is the question where those three are easiest to confuse.

Part VI
Pointlikeness from Non-Spatial Structure

Why the electron is a point in space and nowhere else (Q4 — the new derivational core)

25 The century of the point: from crisis to construction

Q4 is the only one of the six questions that was historically a *crisis* rather than a gap. The classical electromagnetic self-energy of a point charge diverges linearly with the cutoff radius; at the classical electron radius $r_e = e^2/(4\pi\epsilon_0 m_e c^2) \approx 2.8 \times 10^{-15}$ m the field energy alone exhausts the mass. Abraham (Abraham, 1903) and Lorentz (Lorentz, 1909) built extended-electron models and met the stability problem: a ball of charge explodes. Poincaré (Poincaré, 1906) introduced the non-electromagnetic stresses that bear his name to hold it together, at the price of an unexplained new force. Dirac's 1938 classical theory (Dirac, 1938) sharpened the point-charge dynamics into the Lorentz–Dirac equation with its runaway solutions and pre-acceleration — pathologies that remain textbook material today. The discovery of spin made the crisis worse: a classically spinning sphere of any radius compatible with scattering data needs superluminal surface speeds to carry $\hbar/2$ (the observation is as old as the proposal of spin itself; Uhlenbeck & Goudsmit, 1925).

Quantum field theory did not resolve this crisis; it *sidestepped* it. Renormalization (Dyson, 1949; Feynman, 1949; Tomonaga, 1946) keeps the bare-point ontology and absorbs the infinity into a redefinition of parameters, the program detonated by the 1947–48 measurements of the Lamb shift and the moment anomaly (Kusch & Foley, 1948; Lamb & Retherford, 1947). The procedure is consistent and spectacularly predictive, but as an answer to "why is the electron pointlike, and why does that not cost infinite energy?" it answers "by construction, and because we subtract it." Meanwhile experiment has made the point sharper than any theory required: no substructure has appeared in e^+e^- contact-interaction searches, with compositeness scales excluded into the multi-TeV range (ALEPH et al., 2006; Eichten, Lane & Peskin, 1983), corresponding to structural radii below $\sim 10^{-19}$–10^{-20} m (the precise figure is model-dependent, and we deliberately do not quote a sharper one); and the electron magnetic moment agrees with the QED prediction for a structureless point at the 10^{-13} level (Fan et al., 2023), the argument by which Dehmelt assigned the electron an "intrinsic radius" bound orders of magnitude below the scattering bounds (Dehmelt, 1988), via the substructure analysis of Brodsky & Drell (1980) — itself model-dependent, as Dehmelt knew and said. The Standard Model's verdict stands: the electron is pointlike by construction, to the best precision ever attained, for no stated reason.

26 What AX-2 makes a particle: two charges on one composite connection

Before the non-spatial-structure argument, we state the constitutional foundation that this Part — and, it will turn out, Part VII — stands on, because the pointlikeness answer is not an observation about the electron; it is a consequence of what, under AX-2, a particle *is*.

AX-2 (GGEP, the Geometry–Gauge Equivalence Principle) declares that the primitive field of physics is a *single composite geometry-plus-gauge connection* on the bulk (Arisaka, 2026, A1-Constitution): quantum and gauge structure are geometrized, not appended, and the composite object $\mathcal{A}_{\mathrm{tot}} = \omega \oplus A$ — the spin connection of the metric together with the gauge connection — is the whole of the world's structural content (GG-A6-GRIP's TGG pillar; the full deployment is GG-A5-GDOS's Part VI, which this section and Appendix G reproduce in digest (Arisaka, 2026, A5-GDOS)). The consequence for matter is exact and exhausting: a matter excitation couples to the world through the minimal worldline Lagrangian

$$\mathcal{L} \;=\; \tfrac{1}{2}\, m\, g_{\mu\nu}\, \dot{x}^{\mu}\dot{x}^{\nu} \;+\; q\, A_{\mu}\, \dot{x}^{\mu}, \tag{11}$$

and through nothing else — one coupling to the metric sector, weighted by the mass-energy m, and one to the gauge sector, weighted by the holonomy charge q. Varying Eq. (11) yields the single unified equation of motion of GG-A5-GDOS's Part VI,

$$\boxed{m\Big(\ddot{x}^{\mu} + \Gamma^{\mu}_{\nu\lambda}\, \dot{x}^{\nu}\dot{x}^{\lambda}\Big) \;=\; q\, F^{\mu}{}_{\nu}\, \dot{x}^{\nu},} \tag{12}$$

in which the left side is the curvature of the metric (gravity, carried by the scale dimension) and the right side is the curvature of the gauge connection (electromagnetism, carried by the phase dimension): one trajectory, two curvatures, no force ever postulated.

Three consequences carry this Part. *First*, the electron's entire 4D interface with the world is exhausted by the data that contract with the two curvatures: the mass m, the charge q, and the spin label that fixes how its spinor rides the connection — the spin entering not as a third term in Eq. (11) but through the spinor's parallel transport along the same composite connection: connection coupling again, not a new slot. There is no fourth slot. *Second*, each of those data is *connection data*, not matter distribution: q is the integer-quantized holonomy momentum on S^1_θ (charge quantization is the compactness of the phase circle); m is the GFF level set by the dyadic depth along I_r (Appendix C); the spin label is the double-cover tag of the bulk spinor group (Eq. 6). *Third* — and this is the reorientation that dissolves Q4 — a "spatial charge distribution" is not a suppressed feature of such a particle; it is *not a variable of the theory's matter sector at all*. Equation (11) has no slot in which a profile $\rho(\vec{x})$ could be written. The century asked "why is the electron's size zero?"; under AX-2 the prior question is "what made us expect a size?" — and the answer is that pre-GGEP physics mistook the two connection charges for properties of a material body, and then went looking for the body. Status: the worldline coupling (11) and the unified equation (12) are reproduced from GG-A5-GDOS's Part VI, where both chains are derived in full from the 6D bulk; AX-2 itself is a constitutional axiom, and we say so.

Physics intuition. Think of how general relativity retired the question "what pulls the apple?" — nothing pulls it; the apple follows the geometry, and "gravitational force" is bookkeeping for that. AX-2 performs the same retirement for "what is the charged body?": there is no body to which charge is attached; there is a worldline whose two couplings to the one composite geometry are what we had been calling mass and charge. The electron is not a small charged sphere that mysteriously lost its radius. It is a pure position in spacetime dressed with two integers' worth of connection data — and a position has no size to lose.

27 Structure along I_r and S^1_θ

§26 said why no size is *written into* the electron: the worldline couples through two charges, and a spatial profile is not a variable of the matter sector. This section says where the electron's structure actually *lives* — because the electron is not structureless; it is rich with structure, every bit of it along directions that are not space. In the six-dimensional bulk of GG-A2-GG6, the two non-boundary directions are not spatial: Theorem 1 of GG-A2-GG6 forces the bulk $\mathcal{M}_6 = \mathcal{M}_4 \times I_r \times S^1_\theta$ where I_r is the geometrized scale (RG-flow) direction and S^1_θ the compact phase direction (Arisaka, 2026, A2-GG6). Neither I_r nor S^1_θ is a small spatial circle in the Kaluza–Klein sense the words might suggest; they are directions of *scale* and of *phase* — not space, but geometry — orthogonal to space not in the way a fourth spatial axis would be but categorically.

The electron's structure — everything about it that is rich, organized, and worthy of the word — lives entirely along those two directions. Its dyadic seam depth $2^J = 128$, the integer that sets $\alpha^{-1}(M_Z)$ and the denominator 2^{J+L+1} of its Yukawa (Eq. 3), is a coordinate along I_r; its U(1) winding, the integer that quantizes its charge, is a coordinate along S^1_θ; its cascade depth (the basin label of Eq. 7) indexes its position in the GFF landscape hung over those directions. The constant-absorption lineage of GG-A4-Euclid (Arisaka, 2026, A4-Euclid) tells the same story from the side of the constants: what look like dimensionful mysteries in 4D are bookkeeping along the scale direction.

Physics intuition. What is it like for a direction to be "scale"? Every graduate student has already moved along I_r: Wilsonian renormalization — block-spin, coarse-grain, zoom — is motion along a scale axis, and the scale profile e^{-2r} of the canonical metric is that zoom written as geometry. The electron's dyadic depth 2^J is a position along this axis in the same sense that "the physics at 1 GeV" is a position on an RG trajectory — a location in *resolution*, not in any room. The contrast with Kaluza–Klein is then sharp: a KK theory asks how far around a small circle in space a mode wraps, and gets a tower of spatial echoes; the GG-6 question asks how deep in resolution a configuration sits, and a depth leaves no echo in space. Only the first question leaves footprints in a form factor.

We register the structural statement as a proposition with proof by citation, because every ingredient is an established cohort theorem — and we name what it does *not* yet say.

Proposition 27.1 (Non-spatial support; status: assembly of A2/A4/A9 theorems (T-Electron-3))**.** *Every structural attribute of the electron — its mass (a GFF basin level over the scale direction), its charge (a winding integer on S^1_θ), its spin label (a quaternionic double-cover label of the bulk spinor group, Eq. 6), and its dyadic depth 2^{J+L+1} — is a coordinate along the non-spatial directions I_r, S^1_θ or a label of the bulk group action. No structural attribute of the electron is a function on 4D space.*

If the electron's structure has no spatial component, then space, looking at the electron, finds nothing to resolve. That is the intuition. But an intuition is not a form factor, and the distance between them is the honest work of this Part. The gap is real: GG-A2-GG6 contains no theorem that converts Proposition 27.1 into a statement about scattering experiments. We construct that statement now; the one locality property it requires turns out to be supplied by the constitution itself.

28 Mass without self-energy; spin without spinning

Before the form factor, the two dissolutions that Proposition 27.1 already licenses.

Mass without self-energy. The classical crisis of §25 assumed that the electron's mass is energy stored in the 4D field surrounding a point — an integral $\int \frac{\epsilon_0}{2}|E|^2\, d^3x$ that diverges as the support shrinks. In GG-Theory that integral never appears: m_e is the GFF level of the ground basin (§12.1), a property of the landscape over the non-spatial directions, not of any 4D field configuration. There is no self-energy to regulate because the mass was never self-energy. The Poincaré stresses are not explained; they are *unemployed*. We flag the claim's status precisely: this is a dissolution (the problematic quantity is shown never to arise), not a calculation of radiative corrections within QED, whose renormalized perturbation theory remains the correct effective description on the boundary and is untouched here.

Spin without spinning. The spin paradox assumed that $\hbar/2$ of angular momentum must be carried by rotation of a spatial mass distribution. Equation (6) replaces the picture: the electron's spin label is the quaternionic double-cover label of $\mathrm{Spin}(1,5)$ acting on the boundary — group-theoretic data of the bulk readout, not kinematics of a body. Nothing rotates, so no surface speed exists to exceed c. The 4D observer who insists on a rotation finds exactly the paradox history records, because the rotation was never there: spin is the boundary shadow of a bulk algebra whose "$\frac{1}{2}$" counts the double cover, not a revolution rate. Status: the group identification is A2's theorem; the "shadow" reading is interpretive language for the boundary projection of GG-A8-QM, and we mark it as such.

29 The pointlikeness theorem and its observable shadow

29.1 What must be proved — and what merely follows

The question of this Part is geometric — does the electron have spatial structural support beyond a point? — and its answer, built in §26–§28, is constitutional. Experiment, however, accesses that geometry through one interface: a scattering experiment measures the charge form factor $F(q^2)$, and "pointlike" reaches the laboratory as $F(q^2) = 1$ at all accessible spacelike momentum transfers, equivalently the vanishing of every structural radius moment, beginning with $\langle r^2 \rangle = -6\,\hbar^2\, dF/dq^2|_{q^2=0} = 0$. (Throughout, F denotes the *structural* form factor: the Standard-Model radiative dressing of a point vertex — vacuum polarization, the anomalous moment a_e — is calculable, observed, and not at issue; a nonzero a_e is not substructure, which is why Dehmelt's $g-2$ radius argument needed a compositeness *model* to convert precision into femtometers (Dehmelt, 1988).) Compositeness models predict $F(q^2) = 1$ only below their binding scale Λ, with deviations of order q^2/Λ^2 appearing at the scale of the constituents (Eichten, Lane & Peskin, 1983). The GG-Theory claim must therefore be: $F \equiv 1$ *identically, at every scale, forever.*

Physics intuition. A form factor is a ruler made of wavelength. Rutherford's point-charge cross-section is dressed, for an extended target, by $F(q^2)$ — in the static limit the Fourier transform of the charge distribution — so scattering at momentum transfer q asks: does the target look different at resolution $\hbar/q$? The proton answers *yes*, with a slope at $q^2 = 0$ giving its ≈ 0.84 fm charge radius; nuclei answer *yes* with diffraction minima; the electron, probed to scales more than four orders of magnitude below the proton's, has only ever answered *no*. Theorem 29.2 is the claim that nature's answer is *no* at every q there will ever be — the experimental record to date promoted from streak to law.

29.2 The derivation, and the constitutional step that closes it

Proposition 27.1 gives the bulk-side fact: the electron configuration carries no structural data along $\mathcal{M}_4$. The missing step is boundary-side: the form factor is a property of the *readout* — the OGGEP bulk-to-boundary projection (= the operational form of the geometry–gauge equivalence principle: the map by which bulk configurations register as 4D boundary events; GG-A8-QM's framework). If the readout map itself smeared bulk configurations over a 4D length scale ℓ (an instrumental resolution of the bulk–boundary correspondence, so to speak), scattering would measure $F(q^2) \neq 1$ at $q \sim \hbar/\ell$ *even though the electron has no spatial structure*, and conversely. The derivation therefore requires a locality property of the readout map. The constitution supplies it. AX-1 (LC: Locality and Causality) of GG-A1-Constitution is formulated, by explicit constitutional clarification, for open systems — LC "must hold for open evolution maps and measurement instruments, not only for closed unitary dynamics" — and its microcausality clause attaches admissible observables to *points* of the manifold, excluding fundamental extended structure. Imposed strictly on the registration channel, AX-1 yields the required property as a lemma:

Lemma 29.1 (RL — Readout Locality; status: derived from AX-1)**.** *The OGGEP bulk-to-boundary readout map introduces no 4D length scale: the registration of a bulk configuration at a boundary point is local in the boundary coordinates, with any apparent extension of the readout bounded by the wavelength of the probe, not by any property of the registered configuration.*

Proof (channel level; full version in Appendix F, Step 2). AX-1 binds the readout itself: its constitutional statement quantifies over "every admissible boundary intervention protocol" and requires registered boundary records to depend only on data in the causal past, with acausal effective kernels inadmissible; its constitutional clarifications extend this to open evolution maps and measurement instruments, and attach admissible observables to points (microcausality) (Arisaka, 2026, A1-Constitution). A registration kernel carrying an intrinsic 4D length $\ell_{\rm hol}$ must place support either at spacelike separation — barred directly by the constitutional statement — or along the causal past, as retarded memory. Retarded memory is admissible but generates no equal-time spacelike profile: causal response disperses in frequency, while the static structural form factor probes equal-time spacelike correlations only. Hence no admissible readout supplies a spacelike scale; and the probe-wavelength clause of the statement is then the operational restatement of scale-freedom — with the registration scale-free, the only length present in a registration event is the probe's own. The formalization of the static-limit step in the OGGEP channel formalism is registered as open problem D-P3-1. ■

One honesty note accompanies the lemma. AX-1 is an axiom, and a reader who rejects the constitution receives Theorem 29.2 in conditional form — exactly as every theorem of this cohort is conditional on its declared axiom system. What a reader may *not* conclude is that pointlikeness has thereby been answered by fiat: Appendix F (Step 2, first Remark) prices precisely what AX-1 contributes (point-attachment of observables), what it cannot contribute alone (the dissolution of the self-energy crisis, and the permanence of structurelessness at every scale — which require Proposition 27.1 and the lemma jointly), and why the result differs in observable content from the Standard Model's "pointlike by construction."

Theorem 29.2 (Pointlikeness; status: theorem, by AX-2 coupling completeness, Proposition 27.1, and Lemma 29.1 from AX-1 (T-Electron-4))**.** *The electron's structural support in the boundary spatial directions is exactly a point: no structural length exists anywhere in the chain that registers it — not in the matter coupling (AX-2, Eq. 11, which has no profile slot), not in the structural data (Proposition 27.1: all of it lies along I_r and S^1_θ), and not in the readout (Lemma 29.1). Consequently — as pure Fourier bookkeeping, the transform of a point being flat by definition — the structural form factor is identically unity, $F(q^2) = 1$ at every momentum transfer however large: every structural radius moment vanishes exactly, and no substructure exists at any spatial scale.*

Remark 29.3 (On the status of the form factor)*.* The reader should be clear about what role F plays in this paper, because it is *not* the role it has played for forty years of compositeness searches. In a framework with no first-principles account of pointlikeness, the form factor is the primary object — all one can do is measure bounds and push Λ upward. In the present framework the logic runs the other way: the point is a constitutional theorem, and once both its sides are closed — the object by AX-2 and Proposition 27.1, the registration by Lemma 29.1 (the one step the "flat by definition" shorthand silently assumes) — the flat form factor carries no further physics. We retain F for exactly one reason: falsification must name an observable, and experiment speaks F. It is the theorem's shadow on the laboratory wall, and kill criterion F2 watches that shadow; the theorem itself lives upstream, in the geometry.

Proof sketch. By §26, the structural vertex is already the point vertex of Eq. (11): AX-2's matter coupling has no slot for a profile (constitutional Step 0). What remains, for the Fourier corollary to be licensed, is to exclude scale generation by kinematics or by the readout. A deviation $F(q^2) \neq 1$ requires a length scale: F is dimensionless in $q^2\,\ell^2$ for some ℓ characterizing either the probed object or the probing channel. By Proposition 27.1 the electron supplies no such ℓ (its structural scales 2^J, depth, winding are dimensionless coordinates along non-spatial directions, and the basin level m_e enters kinematics, not structure); by Lemma 29.1 the readout supplies none. A function of q^2 with no scale and the normalization $F(0) = 1$ (charge seen whole at zero momentum, which is charge quantization, §12.2) is identically 1. The full argument, including why the scale profile of the canonical metric cannot smuggle in a scale and the comparison with the Kaluza–Klein case (where genuinely *spatial* extra dimensions do produce form-factor towers), is Appendix F. ∎

29.3 The sharp edge

Theorem 29.2 has a falsifiable edge that no compositeness model shares and no agnosticism can blur, and we pre-register it in the strongest available form: *no substructure will ever be found, at any spatial scale, by any probe, at any energy.* Every compositeness model predicts a scale at which structure appears; GG-Theory predicts that the present experimental situation — structurelessness to the limit of every probe — is exact and permanent. **Figure 10** draws the contrast: every rival picture owes structure at *some* scale; this one owes structurelessness at *all* of them.

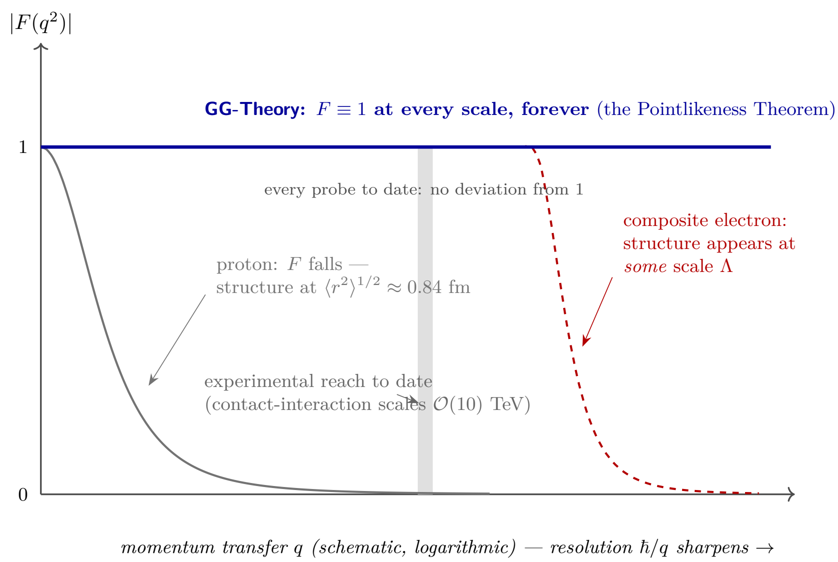

Figure 10: The falsification interface of the pointlikeness theorem, drawn — the theorem's ground is constitutional (§26); this figure shows its shadow on the laboratory wall. A structural form factor $F(q^2)$ answers the question "does the target look different at resolution $\hbar/q$?" The proton (gray) answers yes, with the fall-off encoding its ≈ 0.84 fm charge radius. Every compositeness model (red, dashed) answers "yes, eventually": flat until its binding scale Λ, then structure — the scale may be pushed up, but the model owes one. GG-Theory (blue) answers *no at every scale, forever*: with the electron's structure entirely along the non-spatial directions and the readout scale-free by Lemma RL (from AX-1), $F \equiv 1$ identically. The gray band marks the current experimental reach; all curves are schematic. The first confirmed structural deviation, at any q, kills Part V outright (F2).

Each extension of the contact-interaction reach is a test; the first confirmed structural deviation in any electron form factor kills this Part outright, with no parameter to retreat to (Part VIII, F2). Q4, historically the question on which theories of the electron died, is on this account the question on which the present theory has agreed to die.

30 Part VI in plain English: how the electron can have structure and still be a point

Of the six, this is the only question that was a crisis rather than a gap. A point charge has infinite field energy; a charge of finite size flies apart unless something holds it together. Abraham, Lorentz and Poincaré each tried, and each traded one problem for another. Renormalization made the infinity manageable without making it go away, and every graduate student is taught the subtraction and asked not to look at it too hard.

The proposal here is that the electron has structure and that none of it is in space. It is a point along the three spatial directions and extended along the two that are not — the scale direction and the phase circle. That is not a rhetorical dodge, because it has a consequence any experiment can test: a form factor measures whether a target looks different at finer resolution, and a particle with no spatial extent must return a constant. The Part derives that constant and states the reach at which it would be falsified.

The reason the crisis was a crisis is that everyone assumed structure meant spatial structure. Drop the assumption and the mass needs no self-energy and the spin needs nothing spinning.

Part VII
Why the Electron Moves

The phase fiber, the equivalence principle for charge, and force as geometry (Q5)

31 The sixth dimension is the electromagnetic fiber: a circle over every point

Before any machinery, we state Q5's answer in the form a student can carry out of the room, because the deepest part of it requires nothing the reader does not already own.

Every graduate student knows that electromagnetism is a U(1) gauge theory: the phase of a charged field can be chosen freely and independently at each point of spacetime, and the textbook formalization of that freedom is a *fiber bundle* — over every point of spacetime hangs a circle, and the electron's wavefunction carries, at each point, a position on that circle. In the Standard Model this circle is scrupulously "internal": an abstract bookkeeping space, drawn in every textbook figure as a little ring over spacetime and then immediately disclaimed as not really being anywhere.

The constitutional move of GG-Theory — AX-2, the Geometry–Gauge Equivalence Principle (Arisaka, 2026, A1-Constitution) — is to stop disclaiming the picture. The circle the textbooks draw is the sixth dimension: S^1_θ *is* the $\mathrm{U}(1)_{\mathrm{EM}}$ fiber, attached to every point of $\mathcal{M}_4$ exactly as gauge theory always drew it (**Figure 4**, the green circle). Electromagnetism then needs nothing added to the world: the gauge potential A_μ is the rule for comparing phase between neighboring points — the *connection* of the bundle — and the field strength $F_{\mu\nu}$ is the failure of a phase to come home after transport around a small loop — the *curvature*. A student who has computed an Aharonov–Bohm phase has already measured this geometry once, without being told that is what the measurement was.

Charge follows at once: the electron is charged because it *winds* around the fiber, and winding around a circle comes only in integers — charge quantization is the compactness of the sixth dimension (§32), Klein's century-old insight (Klein, 1926) promoted from curiosity to constitution.

Now the step that answers Q5, and it is Einstein's step taken a second time. General relativity retired the question "what pulls the apple?": nothing pulls it; mass-energy curves the stage, and the apple follows the straightest available path. The equivalence principle is what makes this possible — the geometry is one geometry for all bodies. AX-2 extends the very same principle from the metric sector to the gauge sector: spacetime and the phase circle are not a stage plus a decoration but *one connected geometry*, described by one composite connection. Consequently a winding particle's straightest path through the *combined* geometry bends in space wherever the phase sector is curved, in proportion to its winding number q — and an external electric field is precisely such a curvature, whose spatial direction the bend inherits. The electron "senses" the field's direction because the local

U(1) phase over its position is geometrically linked, through GGEP, to the phases over neighboring points: a proton nearby curves that linkage, and the electron's geodesic leans toward it. Falling toward a proton and falling toward the Earth are one phenomenon read on the two sectors of one geometry — which is exactly what the unified equation of motion, derived in §33.1 and reproduced in full in Appendix G, says with symbols: $m(\ddot{x}^\mu + \Gamma^\mu_{\nu\lambda}\dot{x}^\nu\dot{x}^\lambda) = q\,F^\mu{}_\nu\,\dot{x}^\nu$, metric curvature on the left, fiber curvature on the right, no force anywhere.

Physics intuition. Picture every point of space carrying a small clock dial — the fiber. The electron, being charged, reads the dials as it travels: its quantum phase advances according to the settings it passes. A proton nearby sets the neighboring dials systematically askew, and that pattern of mis-setting *is* the electric field — there is nothing else to it. The electron's "straight" path is the one along which its accumulated phase is stationary (the reader who knows the path integral knows this is not a metaphor but the classical limit of $e^{iS/\hbar}$ with the minimal-coupling term $qA_\mu\dot{x}^\mu$ in S), and through the askew dial field the stationary-phase path bends toward the proton. No message is sent; no force is transmitted; the electron does the only thing matter ever does — it follows the geometry — and its charge merely sets how strongly its path attends to the dial sector. After all, Einstein taught us in 1915 that "force" is what geometry looks like when we forget to count a dimension; GG-Theory's claim is that electricity was the same lesson, waiting for the sixth.

32 Existence, quantization, and value of the coupling

With the fiber picture of §31 in hand, Q5's bookkeeping questions answer themselves in order, and the citations below are records of where each step is proved rather than the argument itself. The parts of the answer that GG-Theory owns outright begin with the existence, the quantization, and the value of the coupling. Existence: the boundary $\mathrm{U}(1)_{\mathrm{EM}}$ is not postulated; it descends from the derived bulk gauge group of GG-A2-GG6 (its Theorem 3), and the photon's masslessness — the reason the force is long-range at all — is the commutant statement of GG-A9-SM's identity section. Quantization: the winding-integer origin of charge (§12.2) is why every source couples in integer units — in Chain (B)'s language (§33.1), electric charge is the integer-quantized holonomy momentum on the compact phase circle, the Kaluza–Klein integer made constitutional. The force law itself follows in §33.1. Value: Eq. (5) — $\alpha^{-1}(M_Z) = 2^J = 128$, completed at zero momentum to the CODATA 137.036 — is the dyadic-closure attractor coordinate: the number Sommerfeld introduced as an input in 1916 (Sommerfeld, 1916), the century's most famous unexplained constant, produced by the same ledger that produced the mass. Status: codebook-level (A9), with the non-primitivity of e at theorem level (A4, T-Euclid-4). We note for completeness that the two most precise atom-interferometric determinations of α currently disagree at $> 5\sigma$ (Rb: Morel et al., 2020; Cs: Parker et al., 2018); the QD-completed prediction is registered against CODATA 2022, and Part VIII phrases the corresponding kill criterion so that the experimental dispute cannot be mistaken for a fence of ours.

33 The force law as composite geodesic motion

§31 stated the principle; this section shows it is not a picture but a derivation. Both classical force laws descend, step by checkable step, from the one bulk action — the content of GG-A5-GDOS's Part VI, reproduced in digest in Appendix G so the reader can run every line without leaving this paper. The foundation is §26's AX-2 worldline.

33.1 Two chains, one bulk

GG-A5-GDOS's Part VI derives, in deliberate parallel and in full pedagogical detail, the two iconic inverse-square laws from the same six-dimensional bulk. *Chain (A)*: integrating the 6D Einstein–Hilbert action over the phase circle (a factor 2π) and then over the scale interval (the scale-profile integral $\int_0^K e^{-2r}dr$) yields four-dimensional general relativity (Einstein, 1915) with $M_{\rm Pl}^2 = \pi M_6^4(1 - e^{-2K})$; the weak-field limit gives Newton's potential (Newton, 1687), and the geodesic equation gives $F = ma$. *Chain (B)*: the gauge connection on the phase circle descends to the 4D Maxwell action (Maxwell, 1865); minimal coupling (Eq. 11) gives the Lorentz force; the static Green's function of the 3D Laplacian gives Coulomb's law. The two chains have the same starting point, the same number of steps, and the same kind of endpoint — and they converge on the single unified equation of motion (12). Newton's law and Coulomb's law are the same equation read on the two curvatures of one geometry: this is the precise, derived realization of Einstein's unification program — the road Kaluza and Klein opened (Kaluza, 1921; Klein, 1926) — and the gravity–electricity dictionary of Appendix G.3 sets the parallel out term by term.

33.2 The answer to Q5

With the unified equation in hand, the question "why does the electron sense the field and move toward the proton?" receives the same kind of answer general relativity gave to "why does the apple fall?" Nothing is transmitted to the apple; the apple follows the metric. Nothing is transmitted to the electron; *the electron follows the composite connection*, of which the proton's presence has shaped the gauge sector exactly as a mass shapes the metric sector. "Sensing" at the fundamental level is generalized free fall — motion on the one geometry that AX-2 says is all there is — and the electric force is not an influence the electron detects but the shape of the electron's world. The three structural ingredients that make the two laws twins — a massless mediator protected by unbroken symmetry, Gauss-law flux conservation in three spatial dimensions (the same Green's function $-1/4\pi r$ on both sides), and a conserved Ward-identity current ($T_{\mu\nu}$ for the metric sector, J^μ for the gauge sector) — are reproduced in Appendix G.4. Status: theorem-level within the framework — both chains are derived end-to-end in GG-A5-GDOS's Part VI from the bulk action, with no force postulated anywhere — and constitutional at the root, since the unification *is* AX-2's content. Where the two laws differ (universal coupling to mass-energy versus quantized coupling to holonomy charge; bulk-set G_N versus boundary-running α) is itself derived, not modeled.

33.3 The division of credit, restated exactly

The refined version of this paper's R4 sentence is the following. *The framework derives the force itself*: the existence, masslessness, and inverse-square form of both laws; the quantization of the charge that couples to one of them; the strength α (Appendix C.3); and the unified equation of motion in which attraction and repulsion reside as the two signs of q in $qF^{\mu}{}_{\nu}\dot{x}^{\nu}$ — the full classical Maxwell–Lorentz system arrives derived, sign structure included, in Chain (B). *QED owns the quantum reading of the sign rule*: that the attraction of opposites and repulsion of likes is, at the mediator level, the signature of spin-1 exchange (where spin-0 or spin-2 would not flip the sign) is a theorem of relativistic quantum field theory (see, e.g., Weinberg, 1995), restated inside the framework by GG-A9-SM's forces section, and credited here as before. Nothing in this sharpened statement blurs the R4 line; it relocates the boundary honestly — the classical phenomenology is derived, the quantum mechanism is QED's, and the framework's boundary theory *is* QED at accessible energies, so the two statements cohere.

34 The open-system layer: what descends, and where

What remains of Q5 after §33.2 is the open-system question: where, in the physics of a charged particle, is there an arrow of time? The answer requires a precision this paper initially blurred, and we state it now in the form the two non-spatial dimensions themselves dictate. *The phase sector moves the electron; the scale sector transmutes it.* Motion in space is the θ-sector geodesic of §31 — conservative, reversible, dissipating nothing: an external field curves the phase connection over *position space*, and the bend it produces is not a descent of anything. Genuine GFF gradient descent — GRIP-In, dissipative and irreversible — lives in the *scale* sector: its landscape is the family stratum, not position space; it transmutes its occupant ($\tau \to \mu \to e$, Part IV) at a point, and it transports nothing. An earlier reading of this paper identified spatial drift with GFF descent on a "tilted landscape"; we withdraw that identification here as mis-sectored — the **INT** tag exists precisely so that readings can be corrected without damage to theorems, and nothing downstream depended on it.

Remark 34.1 (Reading: the dissipative channel of motion is radiation; status: interpretive; supersedes a withdrawn earlier reading)*.* Where, then, does open-system language properly attach to *motion*? At the one place energy actually leaves: radiation. An accelerated charge sheds energy (Larmor's law, Larmor, 1897; the classical reaction force of Dirac, 1938), and it is this — not the conservative geodesic bend — that gives the trajectory of a charged particle its arrow: the classical orbit decays by radiating, the excited atom relaxes to its ground state by the same channel, and in GDOS terms this radiative loss is the open boundary doing to motion what GRIP-In does to particle identity — carrying the system downhill, here in orbital energy, there in basin level. "Sensing," at theorem level, is §31's statement: to be continuously registered against the local fiber geometry. The open-system layer adds only the arrows, each in its own sector: radiation for motion, GRIP-In descent for decay.

Physics intuition. Read a bubble-chamber photograph of a muon with the two sectors in mind, and the whole of this Part is in the picture. The track *curves*: that is the sixth dimension — the phase fiber's curvature bending a conservative geodesic, no energy lost to the bend. The track *tightens* as it spirals: that is dissipation — radiation and ionization, energy leaving through the open boundary. And the track *ends* in a kink with an electron flying on: that is the fifth-dimension sector — GRIP-In descent through a gate, at a point, transmuting the occupant. Three phenomena, three readings, one geometry: the sixth dimension bends the track, dissipation shrinks it, the fifth-dimension descent ends it. The electron's own track differs in exactly one way — it has no endpoint (Theorem 13.1) — **Figure 11** draws the two sectors side by side.

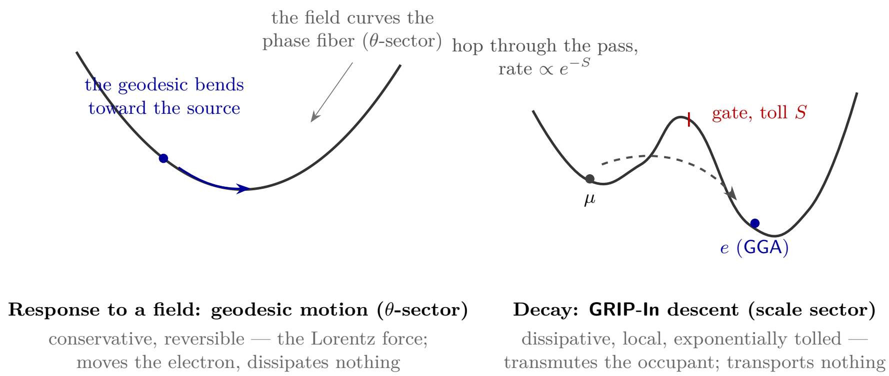

Figure 11: Q5 and Q3 as the two sectors of one geometry. *Left (θ, the sixth dimension):* an external field curves the phase connection over position space, and the electron's geodesic bends toward the source — conservative motion that transports the particle and dissipates nothing (§31). *Right (I_r, the scale sector):* GRIP-In — genuine GFF gradient descent — acts on the family stratum, not on position space: it transmutes its occupant through a gate at exponential cost e^{-S}, at a point, transporting nothing. A muon's bubble-chamber track shows both at once, plus the dissipative channel between them: the sixth dimension bends the track, radiation and ionization shrink it, the fifth-dimension descent ends it. The electron's track differs in exactly one way: no endpoint (Theorem 13.1).

The canonical worked example: the synchrotron — and its gravitational twin. Nature runs the partition as a standing demonstration in every electron storage ring, and GG-A5-GDOS's Part VI now carries the full treatment as its radiative completion (Arisaka, 2026, A5-GDOS); we import the result in digest. The stored electron does three separable things. It *bends*: the cyclotron orbit is the θ-sector geodesic of §31 made hardware — the magnetic field does no work, and the bend descends nothing. It *radiates*: the energy loss (Larmor, 1897; enhanced by the famous γ^4 for relativistic circular motion) is precisely the dissipative channel of Reading 34.1, and the beam cools toward its equilibrium emittance. And it *never ends*: no gate (Theorem 13.1), so the descent runs out of energy, not of electron. GG-A5-GDOS's radiative section sorts these into the canonical GDOS current sector by sector — the orbit is the divergence-free circulation, the radiation damping is the gradient drift, the photon shot noise is the diffusion — and the monotonicity lemma makes beam cooling an H-theorem statement realized in hardware. The status discipline travels with the import: the field equations, power formulas, and current decomposition are theorem-level; the sector *identification* is now itself derived — GG-A5-GDOS's closure subsection traces out the field (Feynman–Vernon) and obtains the drift as the retarded flux, the mobility in closed form with the

Larmor and Peters coefficients exact, and the diffusion with the universal storage-ring constant C_q — and, completing the chain, the covariant kernel itself: a closed-form spectral sum over the derived lock tower, causal manifestly and runaway-free by passivity, with the classical obstruction dissolved by this paper's own Q4 doctrine (the mass is a basin level, not a self-energy ledger). GG-A5-GDOS's Open Problem O7 is thereby Resolved, and the status arrives with the example.

The gravitational twin seals the one-geometry claim. A binary star is the metric-sector synchrotron: the Kepler orbit is circulation; the quadrupole radiation is the dissipative channel; and the Peters drift — the slow shrinkage of the orbit — is the gradient sector on the (a, e) state manifold. The Hulse–Taylor binary pulsar has tracked that prediction for five decades to a few parts in 10^3 (Hulse & Taylor, 1975), and LIGO now records the final seconds of the same descent directly (Abbott et al., 2016). One structural difference is itself instructive: the binary's landscape has no normalizable equilibrium — the inspiral terminates at the merger — whereas the synchrotron beam settles into its equilibrium emittance. The synchrotron relaxes; the inspiral exits; the electron, alone among the three, simply persists.

A muon in the same storage ring would do all of the above *and* decay: drift, cool, and then end at a kink, the scale-sector GRIP-In descent acting at a point. The electron only drifts and cools (**Figure 11**). That asymmetry, visible in any bubble-chamber photograph and now in any light source, is the two-sector partition of this section drawn by nature itself.

We close the Part by registering where Q5 now stands. Its kernel is answered at theorem level by the fiber geometry of §31 and the parallel chains of §33.1: the electron moves because the one composite geometry is curved, and its charge sets how strongly its path attends to the phase sector. The open-system layer adds the arrows, each in its proper dimension — radiative dissipation for motion, scale-sector GRIP-In for decay — both priced as interpretive readings, neither carrying any theorem. The sentence to keep is the partition itself: *the phase sector moves the electron; the scale sector transmutes it; and only what actually sheds energy descends.*

35 Part VII in plain English: the force law as geometry, and the circle that was never abstract

Every graduate student knows that electromagnetism is a U(1) gauge theory: over every point of spacetime hangs a circle, and the electron's wavefunction carries a position on that circle. Every textbook draws the circle and then explains that it is not really anywhere.

This Part takes it literally. If the circle is a direction of the world rather than a bookkeeping device, then charge is a winding number (Arisaka, 2026, W2-Holonomy), its quantization is a counting statement rather than an assumption, and the force law is what a free trajectory looks like after it is projected back into four dimensions. Electricity and gravity become the same kind of statement about two different directions — one the scale interval, one the phase circle — and the dictionary between them is written out term by term.

Whether a reader finds this compelling will turn on whether the two extra directions are believed, which is a fair place for the argument to rest and where the falsification program points. What the Part does not do is derive the coupling's value: that is fixed by the integer ledger, and imported.

Part VIII
Discussion

Significance, uniqueness, the contrast with strings and supersymmetry, falsification, open problems, and objections

36 Significance: summary of the solutions for the six questions

The technical work of the paper is complete; this Part steps back. We first state, in plain terms, what has actually been established for each of the six questions and what each solution buys (§36); we then locate the result against every prior approach known to us (§37) and against the two dominant frameworks of beyond-Standard-Model physics (§38); we consolidate the falsification program (§39); we lay out the open problems at full length (§40); and we close with the objections a critical reader should raise, and our answers (§41) — the triumph-before-triage ordering this cohort uses deliberately, so that the defensive case is read after the positive one, not instead of it.

36.1 The six solutions, one by one

Q1 (Identity) — solved at two layers, within the declared axiom system. The sameness layer: every electron is the readout of the *same* unique ground attractor of the *same* boundary stratum (Theorem 11.1); sameness stops being a convention of the formalism and becomes a uniqueness theorem of a landscape. The content layer: the values themselves are no longer inputs — $y_e = 3/1{,}024{,}000$ from five integers, m_e at the declared 1.9×10^{-4} residual, charge quantized by winding with $\alpha^{-1} = 2^J + N^2$, and spin-$\frac{1}{2}$ forced by $\mathrm{Spin}(1,5) \cong \mathrm{SL}(2,\mathbb{H})$ rather than chosen from Wigner's menu. What it buys: the only complete answer we know of to "why is every electron the same, *and the same as what*?" — the second half of which no field ontology can address.

Q2 (Stability) — solved as ground-state-ness, with the textbook argument recovered as a consistency check. The electron cannot decay because its basin is the global minimum and possesses no exit gate (Theorem 13.1); the lightest-charged-particle argument survives *inside* the framework, with charge conservation now derived rather than postulated. What it buys: "absolute" stability stops being an accident of an input spectrum and becomes the defining property of a terminus — and it yields a sharper experimental posture, since even charge-violating channels are forbidden by the landscape, not merely by bookkeeping.

Q3 (Copies) — solved by import, with the fences carried visibly. The muon and tau are the depth-1 and depth-0 basins of the electron's own landscape — excited states in the literal, spectroscopic sense — and the ladder ends at three by the budget arithmetic of GG-P2-N3, conditional exactly on its declared inputs (CP violation observed; the coupling clause; the integrality theorem L-INT with residue R-INT). What it buys for *this* paper: the unification of Q2 with Q3 — the same finite resource that stops the ladder guarantees the terminus is reachable — and the honest division of labor that lets the electron paper stand on the count without re-proving it.

Q4 (Pointlikeness) — solved by dissolution, the one genuinely new derivation of this paper. The electron appears as a point in space because, under AX-2, a particle's entire interface with the world is two charges on one composite connection — there is no slot in which a size could be written (§26) — and because none of its structure is *in* space: every structural datum lives along the scale direction I_r and the phase direction S^1_θ (Proposition 27.1); the mass is a basin level, so the self-energy crisis never starts; the spin is a double-cover label, so nothing spins; and the readout cannot smuggle a length back in, because AX-1 binds measurement instruments themselves (Lemma 29.1) — the flat form factor then following as pure Fourier bookkeeping, retained only as the falsification interface (Theorem 29.2 and Remark 29.3). What it buys: the first statement in the cohort — to our knowledge, the first anywhere — that converts "why pointlike?" from an experimental streak into a scale-free theorem with a kill criterion.

Q5 (Sensing) — solved at constitutional depth, with the open-system gloss priced. The force law itself is derived: Newton's and Coulomb's laws descend in parallel from the same bulk, converging on the unified equation of motion in which gravity and electricity are the two curvatures of AX-2's single composite connection — so that responding to a field is generalized free fall (§33.2; GG-A5-GDOS's Part VI, reproduced in Appendix G). The coupling's existence, quantization (holonomy momentum on S^1_θ), and strength ($\alpha^{-1} = 137$, QD-completed) are derived; the open-system arrows are priced in their proper sectors — radiative dissipation for motion, scale-sector GRIP-In for decay — as interpretive readings; the quantum reading of the sign rule is QED's theorem, credited. What it buys: Einstein's unification realized at exactly the point a student first meets electricity — the electron and the apple obey one law — together with the three-phenomena reading of a bubble-chamber track: the sixth dimension bends it, dissipation shrinks it, the fifth-dimension descent ends it.

Q6 (The twin) — solved by import at theorem grade, with the same-basin reading priced and its promotion registered. The origin of antiparticles is imported from GG-P5-CPT: the twin is forced in the real bulk, before quantization, by the agreement of two independently forced real structures — the circle's i and the clock's i — with the charge flip definitional for fermions (Part V). The positron is then read as the conjugate readout of the electron's one basin: mass equality trivial rather than enforced, and the sixth question collapsing into the first. What it buys: the only account we know of in which "why does the electron have a twin?" and "why is every electron identical?" are the same question — answered once, by counting objects correctly. The reading's promotion to a proved spinor-level corollary remains registered as D-P3-4, deliberately open.

36.2 The conjunction, and the solutions at a glance

Table 4 compresses the Part into one view. The significance of the paper is not any single row; rows have appeared before, in fragments, throughout a century of literature. The significance is the *column*: one fact — the electron is the unique ground state of its stratum — generating all six rows at once, each with a named status, each with a declared failure mode. Remarkably, the six questions turn out to have needed each other: the values of Q1 are basin data, the stability of Q2 is basin topology, the copies of Q3 are the basin's neighbors, the twin of Q6 is the basin's conjugate orientation, the pointlikeness of Q4 is the basin's orientation relative to space, and the sensing of Q5 is the basin's response to tilt. No fragment-by-fragment program could have found that structure, because the structure *is* the conjunction.

Table 4: The six solutions at a glance. Status tags as in §3; the full per-step ledger is Appendix B. One row per question and one sentence per answer, meant to be read before the derivations rather than after them. The status column is the honest half of the table: it records the grade at which each sentence is held, and the grades are not uniform across the six.

Q	The solution, in one sentence	Status
Q1	One deepest basin, one readout — and the basin's data are the measured values	THM (GDOS) + codebook; spin THM
Q2	The ground basin has no exit gate; nothing is downhill from the bottom	THM given GFF-ST7
Q3	μ, τ are the higher basins; the budget pays for exactly three	Imported (EMP + coupling clause + L-INT/R-INT)
Q4	A particle is two charges on one connection (AX-2) — no slot for a size; readout adds no length; $F \equiv 1$ forever	THM via Lemma RL from AX-1 + AX-2 coupling
Q5	Force = composite geodesic motion (Newton & Coulomb, one bulk); coupling, α derived; arrows: radiation (motion), GRIP-In (decay)	THM (GG-A5-GDOS Part VI) + codebook; arrow readings INT
Q6	The twin is forced in the real bulk; the positron is the same basin read in the conjugate orientation	THM (imported: T-P5-A/B/C, C2) + INT (named); D-P3-4

36.3 What the solutions change

Three ledgers move. For the Standard Model: of the quantities the electron contributes to the input list — m_e, the charge unit, the representation choice, the family count — none remains a pure input within the framework; each is now a theorem, a codebook entry, or a fenced conjecture with a declared status. For the cohort: the electron becomes the charter case of the GGA principle — the simplest stratum on which identity-and-stability-as-ground-state-ness can be exhibited end to end —

and Parts III–VII of this paper are, in effect, the worked example that GG-A11-Origin's cascade generalizes through eighteen layers. For method: Q4's resolution demonstrates that the open-system, non-spatial commitments are not philosophical luxuries; they are load-bearing — remove either, and the six solutions collapse back into six mysteries (§43). After all, the test of a foundation is not how much it explains on a good day, but how much stops being explainable the moment you take it away.

36.4 The electron on the two fibers

The six solutions sort, and the sorting is the cohort's recent campaign made local (GG-W1-Symmetry; Arisaka, 2026, P5-CPT; Arisaka, 2026, A8-QM). The campaign's instrument is one exact statement: *holonomy requires closed loops, and an interval has none.* The compact circle S^1_θ is nothing but closed loops — everything on it is holonomy, quantized and protected, its transport a group; the scale interval I_r can hold no holonomy at all — its transport composes only forward, a semigroup. Sorted on this anatomy, the electron divides cleanly in two. Everything about it that is *identical and permanent* is circle-side data: the charge (a winding number), the spin, the representation, identity itself — holonomy classes on the fiber that remembers. That is Q1's solution said topologically: every electron is the same because every electron is the same *class*, and classes do not age, do not wear, and admit no continuous deformation for any boundary operation to apply — sameness needs no enforcement mechanism because the fiber it is written on has nothing that could enforce a difference. Everything about the electron that is *placed and priced* is interval-side: the mass — the address of the ground basin at the descent's terminus — the muon's descent rate (a GRIP-In event along the one-way fiber, §17), and stability itself, Q2's no-exit reading: the semigroup below the ground basin has nowhere further to carry the state, and cannot re-ascend, because ascent would be the inverse transport the fiber does not possess. The positron, Q6, is the same circle-side class read in the mirror orientation — which is why it shares the mass to the last digit while negating every charge: the interval's address is orientation-blind; the circle's labels are not.

In one sentence: *an electron is a holonomy class wearing a mass — the class is the circle's, the mass is the interval's.* The six questions stayed open for a century in part because the two halves were misfiled — the first half mistaken for a convention of the formalism (identity as bookkeeping), the second half for an input (the mass as a measured constant). The campaign's anatomy files them correctly: one half is topology, the other is dynamics, and the electron is the simplest object in nature on which both fibers have signed their work.

37 Uniqueness: comparison with prior approaches

No prior approach known to us answers more than one of the six questions, and each pays for its single answer with a commitment the present framework does not need. We review them at full strength — the reader should hear each at its best before the comparison is scored.

Wheeler's one-electron universe. The most celebrated previous attempt to explain electron identity is Wheeler's 1940 suggestion, relayed in Feynman's Nobel lecture (Feynman, 1966), that all electrons are one electron weaving forward and backward through time, positrons being the backward strands. It is the correct *kind* of answer — identity explained by uniqueness of an underlying object — and it remains, eighty-six years later, the most imaginative one-line proposal in the subject. It failed empirically (the universe is not positron-balanced, and the worldline bookkeeping has no answer for net lepton number) and conceptually (it explains sameness but neither the values, nor stability, nor the generations, nor pointlikeness). The present account preserves Wheeler's insight in a form that survives: what is unique is not the particle's worldline but the attractor it reads out — one basin, many readouts, no positron bookkeeping required. And the replacement of a worldline by an attractor is precisely what lets the account reach across the sky. Wheeler's mechanism is *causal*: one particle threads every electron's place, so identity is carried by a shared trajectory. That is exactly the kind of explanation that cannot survive the second horizon problem of GG-A10-Cosmos (Arisaka, 2026, A10-Cosmos) — electrons in causally disconnected regions share no trajectory, and a worldline that must visit them all is no more available than a signal that must reach them all. The attractor account is *acausal*: identity is a property of one landscape read out everywhere at once, requiring no shared history and no shared worldline (Corollary 11.2). Where Wheeler's picture needs the electrons to have been connected, the GGA needs only that they be boundaries of the same bulk — which is why the one-basin reading answers across the horizon where the one-worldline reading cannot. The differences are auditable: GGA uniqueness is a theorem within a stated framework rather than a picture; it derives the values; it covers all six questions; and it is falsifiable on five declared criteria. Wheeler's question to Feynman — "why do all electrons have the same charge and the same mass?" — is, we believe, answered here in the spirit in which it was asked.

Compositeness and preon models. The structural tradition — the electron as a bound state of more elementary constituents — is the conservative bet on Q4, and its best versions were genuinely economical: in the rishon model (Harari, 1979; Shupe, 1979), the summit of the lineage Pati and Salam opened (Pati & Salam, 1974), two constituents and their anti-partners generate the entire fermion spectrum of one family, an arithmetic elegance the codebook reader will recognize as kindred in spirit. The tradition answers Q3 by construction (generations as excitations of the bound system) and promises Q1's values as binding-energy calculations. What it could never do is reconcile the promise with the point: compositeness at scale Λ predicts form-factor deviations of order q^2/Λ^2 and a spectroscopy of excited states at Λ (Eichten, Lane & Peskin, 1983), while the electron's mass sits five orders of magnitude *below* any allowed binding scale — the notorious mass paradox: a bound state light compared to its own inverse size requires extreme fine-tuning, precisely what 't Hooft's anomaly-matching analyses formalized ('t Hooft, 1980). Forty years of contact- interaction searches have pushed Λ upward without limit in sight. The present framework keeps the tradition's two real insights — the electron *does* have structure, and the generations *are* excitations — and relocates both where the searches cannot refute them: along directions that are not space.

The geometric-electron tradition (Kerr–Newman). A quieter lineage sought the electron in general relativity itself. Carter's analysis of the Kerr–Newman solution (Carter, 1968) noted the remarkable fact that a KN source with the electron's mass, charge, and spin has gyromagnetic ratio $g = 2$ — Dirac's value, from pure geometry — and a tradition of "electron as KN geometry" models followed. The instinct — electron properties are geometric data — is exactly the present framework's instinct, and the $g = 2$ coincidence deserves more respect than it usually receives. The obstacles are structural: the KN geometry at electron parameters has a naked ring singularity of Compton-scale extension in *space* (colliding with Q4 rather than solving it), no quantization of charge or spin, no second and third generation, and no stability statement. The lesson we draw: geometry was the right language but 4D spacetime was the wrong manifold — the electron's geometry lives in the bulk directions, where rings, dials, and singularities are replaced by windings, integers, and basins.

QFT identity, stated at its strongest. The field-theoretic treatment of indistinguishability (permutation symmetry of the quanta of one field; see, e.g., Weinberg, 1995) is the standard professional answer to Q1 and is engaged at full strength in §11.1: it is correct, it is exact, and it is the reason no working physicist loses sleep over electron identity. It is also bookkeeping — sameness is automatic once one field is posited, and the posit (which field, which values, which representation) is where the question lives. We emphasize what the present paper does *not* claim: it does not claim QFT is wrong about identity; it claims QFT's answer has a second half, and derives it. The boundary effective theory of the framework *is* a quantum field theory; the field ontology survives as the boundary description of the basin readout.

Anthropic and landscape treatments of the values. The remaining modern position on Q1's values is environmental: m_e and α vary across a multiverse of vacua, and we observe values compatible with observers (Susskind, 2003). Stated honestly, this is not an answer to "why these values" but a principled argument that the question has no answer — a position consistent, hard to falsify by design, and corrosive to the codebook program: if the values are environmental, a formula like $\alpha^{-1} = 2^J + N^2$ can only be numerology. The present framework makes the opposite bet, and the bet is testable: the codebook either continues to survive ever-sharper measurement at its declared precision (P5) or it breaks. One of the two research programs is wrong, and unusually for foundational disputes, the data will eventually say which.

The classical extended electron. Abraham, Lorentz, and Poincaré sought the electron's structure in space and met the self-energy crisis; Dirac formalized the point limit and met runaways (Abraham, 1903; Dirac, 1938; Lorentz, 1909; Poincaré, 1906). Their failure was instructive in a way the present paper finally makes precise: they were right that the electron has structure, right that the structure is physical, and wrong only about the manifold it inhabits. Part VI locates their impasse exactly — structure in space costs self-energy and spin paradoxes; structure along scale and phase costs nothing in space at all.

The sister derivation, and the division of labor. All comparisons regarding the family count (Dobrescu–Poppitz bounds, modular flavor symmetry, NCG, division algebras, anthropics applied to N) are owned by GG-P2-N3 (its §11) and not duplicated here. What is unique to the present paper, against every entry above, is the conjunction: no prior approach attempted all six questions as one object, because no prior framework had the one fact of which the six are faces. That — not any single ingredient — is the uniqueness claim, and §41 defends it against the strongest objections we could construct.

38 Sharp contrast with supersymmetry and string models

The two dominant frameworks of beyond-Standard-Model physics deserve more than a paragraph in §37, because the contrast with them is uniquely sharp and uniquely instructive: GG-Theory shares most of its technical machinery with string theory — and commits to the opposite answer on every question this paper is about. This section adapts, for the electron, the full treatment given in GG-A2-GG6's comparison Parts (Arisaka, 2026, A2-GG6).

38.1 Same machinery, opposite commitments

A reader trained in string theory will recognize nearly every tool in this paper's upstream chain: anomaly cancellation by a modified Bianchi identity (the Green–Schwarz mechanism (Green & Schwarz, 1984), of which BI-6 is the six-dimensional descent), warped throat geometry (the Randall–Sundrum lineage (Randall & Sundrum, 1999)), holographic projection from bulk to boundary (Maldacena, 1998), and instanton actions counting tunneling between vacua. The machinery is shared; the constitutional commitments are opposite, and they are exactly two. String theory takes the extra dimensions to be *spatial* and the fundamental objects to be *extended*; GG-Theory takes the extra dimensions to be *non-spatial* (a scale direction and a phase direction) and the fundamental excitations to be *point-like* (AX-1's microcausality clause). Everything this paper says about the electron flows from those two commitments — and everything testably different between the frameworks flows from them too.

38.2 Spatial dimensions carry moduli; the landscape follows

A spatial extra dimension is a Riemannian direction with an intrinsic length, and an intrinsic length is a dial. The Kaluza–Klein circle has a radius; the Calabi–Yau manifolds of superstring compactification (Candelas et al., 1985) carry continuous Kähler and complex-structure moduli — shapes and sizes that nothing in the theory fixes. The structural consequence is the landscape: the moduli space of compactifications supports $\sim 10^{500}$ vacua (Kachru et al., 2003) (Susskind, 2003), and the values of the low-energy constants — including m_e and α, the subjects of Q1 — become environmental selections rather than predictions. GG-Theory's two further directions carry no dials at all: I_r is the renormalization-group coordinate $r = \ln(E_{\text{seam}}/\mu)$ with $E_{\text{seam}} = M_{\text{Pl}}/2$, dimensionless, with an *integer* endpoint $K = 35$ fixed by the Diophantine ledger; S^1_θ is a topological circle whose metric component is fixed to unity by the canonical-metric theorem — a phase, not a shape. Where the string construction has continuous moduli, the GG-6 construction has five integers; where the landscape has 10^{500} vacua, the ledger has exactly one solution (GG-A2-GG6, Theorem 6). For the questions of this paper the consequence is direct: in a landscape, Q1's values are unanswerable in principle; in a ledger, they are theorems or they are false.

38.3 Supersymmetry: the partner answer and the basin answer

Supersymmetry is the other great structural bet, and its logic is worth stating fairly: pair every boson with a fermion so that quadratic divergences cancel, stabilizing the Higgs hierarchy; embed in a GUT and the couplings unify; add R-parity and the lightest superpartner is dark matter. It is a beautiful architecture — and for the six questions of this paper it adds nothing structural (on the sixth it inherits quantum field theory's formal answer unchanged). SUSY does not explain why electrons are identical (the selectron is a new field, not an explanation of the old one); it does not explain electron stability (still lightest-charged bookkeeping); it does not predict three generations (the family count is as free in the MSSM as in the SM); it makes the pointlikeness question *harder* (every SM point now has a partner point, doubling the unexplained); and it adds its own unanswered identity question (why is every selectron identical?). Meanwhile its sharp prediction — superpartners at the electroweak-to-TeV scale — has met four decades of null results. The GG-6 alternative spends nothing on partners: stability is topology (no exit gate), the hierarchy is carried by the integer scale depth ($M_{\text{lock}} = \frac{1}{2}M_{\text{Pl}}e^{-35}$), and the electron needs no superpartner for any of its five properties to be theorems. The two bets are cleanly separable by experiment: a selectron discovery would be a triumph for one and an embarrassment for neither's electron sector — but a confirmed electron substructure or a fourth family would kill this framework while merely re-parameterizing SUSY. Asymmetric falsifiability is the deliberate posture here (§39).

38.4 The electron as the cleanest discriminator

Table 5 scores the three pictures against the six questions and their observables. One row deserves emphasis, because it is decisive in principle: a string electron is an extended object with a scale (ℓ_s), and at that scale — wherever it lies — its form factor departs from unity and a Regge tower of excitations exists. The departure may sit at experimentally hopeless energies; the point is structural: *string theory owes structure at some scale, supersymmetry owes a partner at some scale, and GG-Theory owes the absence of both at every scale.* The flat blue line of **Figure 10** is this paper's signature in a single stroke: any confirmed structure kills it (F2), while every null result that disappoints a compositeness or string-scale search is, for this framework, another passed test.

38.5 Honest credits

Three credits, stated without reluctance. String theory remains the most developed candidate for a UV-complete quantum theory of gravity, and nothing in this paper addresses quantum gravity at that depth; the Green–Schwarz machinery this cohort's anomaly structure descends from was a string-theoretic discovery (Green & Schwarz, 1984; Green, Schwarz & Witten, 1987); and the scale-geometry intuition that makes **Figure 4** natural entered physics through the string-adjacent literature (Randall & Sundrum, 1999). The honest statement of the contrast is therefore not "strings wrong, GG-6 right"; it is that the two frameworks bought different things with the same machinery. String theory bought mathematical depth and UV-completeness, and paid with moduli, the landscape, and the permanent deferral of every question this paper is about. GG-Theory bought the six answers and zero dials, and pays by standing permanently in front of the experimental gun

Table 5: The electron in three frameworks. "Owes" marks what each framework predicts must exist at some scale; the verdicts are this paper's declared kill criteria (§39). The three columns are three frameworks answering the same questions about the same particle, so the comparison is like for like. The *owes* row is the one that decides anything: it records what each framework requires to exist that has not been seen, which is the axis along which any of the three can be retired.

	Superstring	**SUSY (MSSM)**	**GG-Theory**
Extra dimensions	six–seven, *spatial*, with moduli	none required	two, *non-spatial* (scale, phase), zero moduli
Electron extension	string scale ℓ_s: $F \neq 1$ there; Regge tower	point by construction	$F \equiv 1$ at every scale (Thm., via Lemma RL)
Identity (Q1)	field convention; values environmental (landscape)	field convention; values free	uniqueness theorem; values from five integers
Stability (Q2)	bookkeeping	bookkeeping	no-exit-gate theorem
Generations (Q3)	topology-dependent (e.g. $\lvert\chi\rvert/2$); not forced	free parameter	forced at $N = 3$ (P2, fenced)
Antiparticle (Q6)	inherited from QFT, formal	inherited from QFT, formal	forced in the real bulk, pre-quantization; positron = conjugate readout (P5 import, fenced)
Owes at some scale	string excitations	superpartners	nothing — forbidden forever

(§39) — with quantum gravity delegated to the cohort's bulk papers rather than solved. A reader may reasonably prefer either purchase; what the reader can no longer do, after this section, is regard them as the same kind of theory that differs only in taste. After all, the deepest difference between two frameworks is never what they explain — it is what they are willing to be killed by.

39 Prediction for falsification

We consolidate the paper's entire empirical exposure in one section, in the cohort's pre-registration discipline: each prediction is stated with its current anchor, its experimental future, and its *live falsifier* — the specific observation that would kill it. The anchor table with sources is Appendix H; Table 6 summarizes with declared classes.

P1 — The electron never decays. *Prediction:* no electron decay, in any channel, at any rate — including charge-violating channels that bookkeeping arguments cannot address; the basin has no gate (Theorem 13.1). *Anchor:* $\tau_e > 6.6 \times 10^{28}$ yr at 90% C.L. (Borexino Collaboration, 2015), more than eighteen orders of magnitude beyond the age of the universe. *Future:* every next-generation low-background liquid-scintillator program (the Borexino lineage, including JUNO-class detectors) extends the reach; the prediction is that the bound improves forever, without limit. *Live* *falsifier (F1):* observation of electron decay in any channel. No appeal to conditioning is available: Theorem 13.1's GDOS-internal status would not survive its empirical falsification.

P2 — No substructure at any scale, ever. *Prediction:* the structural form factor is identically unity (Theorem 29.2); contact-interaction and form-factor searches return null at every energy, with no compositeness scale Λ anywhere (Eichten, Lane & Peskin, 1983). *Anchor:* $\mathcal{O}(10)$ TeV contact-interaction reach (model-dependent); $g-2$ consistency at the 10^{-13} level. *Future:* FCC-ee / ILC / CLIC-class e^+e^- programs push effective compositeness scales toward and beyond 10^2 TeV; precision Møller and Bhabha scattering sharpen the low-q^2 slope. Every extension is a test this paper has agreed in advance to face. *Live falsifier (F2):* a confirmed structural deviation of any electron form factor from unity, at any energy — which kills Part VI outright with no parameter to retreat to, and, under Lemma 29.1, reaches the constitution itself: confirmed substructure falsifies AX-1's point-locality within the framework.

P3 — a_e remains pure Standard-Model dressing of a structureless point. *Prediction:* the measured anomalous moment continues to agree with the Standard-Model computation (QED to high order, plus the small hadronic and electroweak terms) for a point fermion, using an independently measured α; no *structural* contribution ever appears. *Anchor:* $g/2$ measured to 0.13 ppt (Fan et al., 2023), superseding Hanneke et al., 2008, against the tenth-order computation (Aoyama et al., 2012); the SM test currently limited by the $> 5\sigma$ Rb/Cs disagreement in α (Morel et al., 2020; Parker et al., 2018). *Future:* next-generation Penning traps and the resolution of the α dispute promote this to a test at the few-10^{-13} level. We register the scope honestly: this paper engages $g-2$ qualitatively, as the empirical anchor of structurelessness; a quantitative GG-Theory statement is open problem D-P3-3. *Live falsifier:* an a_e anomaly that survives the α-dispute resolution and the SM-theory error budget would indicate structure and trigger F2's logic.

P4 — No fourth charged lepton. *Prediction:* the ladder ends at three — imported from GG-P2-N3 with its complete conditioning (§16), and therefore carried here as a *conditional* class. *Anchor:* LEP lepton counting $N_\nu = 2.9963 \pm 0.0074$ (ALEPH et al., 2006). *Future:* a Tera-Z run at FCC-ee would sharpen N_ν by an order of magnitude; direct fourth-generation searches continue at hadron colliders. *Live falsifier (F3):* a fourth sequential charged lepton (or a fourth light neutrino at multi-σ). As §16 records, Q2's no-exit-gate statement would survive unless the new state were charged and lighter than the electron — in which case everything falls.

P5 — The values hold at declared precision. *Prediction:* m_e agrees with the QD-completed codebook value at the declared 1.9×10^{-4} residual, and α^{-1} with its QD completion, as GG-A9-SM reports, against CODATA (CODATA, 2022; Particle Data Group, 2024). This is a *postdiction audit*: the numbers were known before the codebook existed, and the class label says so. *Future:* the residual itself is the open frontier — D-P3-5 records what sharpening the QD layer would mean, and what breaking it would mean. *Live falsifier (F4):* once the Rb/Cs dispute is resolved, a settled α^{-1} incompatible with the QD-completed prediction at its declared precision, or an m_e determination outside the declared residual. The experimental dispute is not a fence of ours, and we do not hide behind it.

F5 — the theoretical falsifier. A demonstrated flaw in the AX-1 derivation of Lemma 29.1 — for instance, an admissible OGGEP registration kernel carrying a spacelike scale consistently with AX-1 — would demote Theorem 29.2 to conditional status and reopen the fence this paper closed. The lemma's proof is registered precisely so that it remains under audit; §41, Objection 15, hosts the strongest version of the attack we could construct.

F6 — the mirror falsifier. A *confirmed* electron–positron asymmetry — in mass (current bound $|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$, 90% C.L.), in charge magnitude ($|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$), or in g-factor ($(g_{e^+} - g_{e^-})/g = (-0.5 \pm 2.1) \times 10^{-12}$) (Fee et al., 1993; Hughes & Deutch, 1992; Van Dyck et al., 1987). For the standard account such an asymmetry would violate the CPT theorem; for this paper it is sharper — it would falsify the conjugate-readout reading of Part V (there is no pair whose members could differ) *before* it falsified CPT. Permanent, two-sided exposure, running now.

Table 6 summarizes with each entry's class declared in the cohort's pull-table discipline: a **Forward** prediction risks something not yet measured; a **Postdiction audit** checks consistency against numbers already known; a **Conditional** entry inherits named fences.

Table 6: The predictions of this paper, with declared classes (cohort pull-table convention). Anchors as of June 11, 2026 (Appendix H). Each row is a prediction, the measurement that currently bounds it, and the class it is declared in, so that a falsifiable commitment can be told from a consistency check without reading another line. The anchors carry a date because they move, and the class is what a null result would retire.

ID	Prediction	Current anchor	Class
P1	Electron never decays; bound improves forever	$\tau_e > 6.6 \times 10^{28}$ yr	**Forward**
P2	No substructure at any scale, ever ($F \equiv 1$)	no deviation to $\mathcal{O}(10)$ TeV reach	**Forward**
P3	a_e stays pure SM dressing of a point	$g/2$ at 0.13 ppt	**Forward** (qualitative)
P4	No fourth charged lepton	LEP $N_\nu = 2.9963(74)$	**Conditional** (P2 fences, §16)
P5	m_e, α^{-1} at declared QD precision	CODATA 2022	**Postdiction audit** (1.9×10^{-4} declared)
P6	Electron–positron equality exact, forever (one basin, two readouts)	mass 8×10^{-9}; charge 4×10^{-8}; g 2.1×10^{-12}	**Forward** (kills via F6)

What would *not* falsify this paper. Pre-registration cuts both ways: we state the negative space, so that no future accommodation can be smuggled in as if it had been intended. A resolution of the Rb/Cs α dispute in *either* direction within the declared QD tolerance does not falsify P5. New heavy states that are not sequential leptons — vector-like fermions, sterile neutrinos, exotic scalars —

do not trigger F3, which is about a fourth copy of the family pattern; they would bear on the cohort elsewhere. An anomaly in the *muon's* $g-2$ does not trigger F2 (the muon is a non-ground basin, and its physics carries additional structure imported from GG-P2-N3); only electron-side structure does. And precisely this has occurred: GG-P2-N3's rigidity lemma proves the budget underivable from the bulk data alone, sharpening D-P3-2 exactly as anticipated without killing Q3's import, which is conditional by declaration. What remains, after the negative space is drawn, is a paper that can be shot in six specific places — and nowhere else without first proving it said what it did not say.

The asymmetry, restated. Every rival picture in §38 owes something at some scale; this paper owes absences — no decay, no structure, no fourth copy, forever. An absence can never be verified, only tested again; this is sometimes raised as a Popperian complaint, and §41 (Objection 14) answers it in full: a universal absence is the *most* falsifiable kind of claim there is, refutable by a single event at any energy, in any decade, by any experiment. The paper's posture is maximal exposure, deliberately chosen. After all, the six questions waited a century for an answer; the least the answer can do is stand where it can be shot.

40 Open problems

Seven problems are open, listed in increasing order of how much of the paper they could move. For each we state the problem, why it matters, and what would count as a solution — the cohort's convention for keeping its to-do list as auditable as its claims. Each entry is registered as D-P3-N — "D" for registered debt — since the cohort-wide O-Suffix-N convention is reserved for the numbered objections (§41).

D-P3-1: Formalize the static limit of Lemma RL. *Problem:* the channel-level derivation of Lemma 29.1 (Appendix F, Step 2) contains one step stated at physicist's rigor — that retarded registration memory contributes nothing to the elastic, zero-energy-transfer structure function. *Why it matters:* this is the only step of the paper's one new derivation that is not yet theorem-grade; F5 lives here. *What counts as a solution:* a theorem in the OGGEP open-channel formalism of GG-A8-QM — kernel $\mathcal{K}(t,t')$ retarded, output: the equal-time structure function of the registered record equals that of the registered configuration — or a counterexample, which would trigger F5. We judge this formalization rather than missing physics; the judgment is itself part of what a referee should audit.

D-P3-2: The inherited fence (the coupling clause and R-INT). *Problem:* the capacity of the family stratum rests on the coupling clause together with the integrality theorem L-INT of GG-P2-N3, whose single topological residue R-INT is discharged on the benchmark background by the κ-bridge theorem of that paper's Appendix H and remains open off it, exactly as recorded in GG-P2-N3 (its §12) and GG-A6-GRIP (M10). *Why it matters:* Q3's upper bound — and with it the "exactly two copies" half of the conjunction — carries this conditioning at every layer. *What counts as a solution:* closure of the residue across the intended class — the warped and relative refinements that appendix declares — everything else is settled: the induced connection is constructed (Berry transport, forced at Born-grade by GG-P2-N3's adiabatic theorems), the $\lfloor J/2 \rfloor$ question is dissolved by the form-robustness classification, the bulk-only route is closed by the rigidity lemma, and the benchmark case of the residue is closed by the κ-bridge theorem. Resolution upstream automatically sharpens Part IV; nothing in this paper can shortcut it.

D-P3-3: A quantitative GG-Theory statement for a_e. *Problem:* this paper predicts the electron's structural contribution to a_e is exactly zero, qualitatively. Can the framework say more — either a proof that the GDOS readout contributes nothing to all orders, or a computed bound? *Why it matters:* $g - 2$ is the most precisely measured property of any particle; a framework statement at the 10^{-13} level would convert P3 from qualitative to sharp. *What counts as a solution:* a boundary-channel computation with declared status at every step — and we state plainly that this is new physics requiring its own paper and its own fences; done carelessly it would be numerology, and the cohort would rather leave it open than do it carelessly.

D-P3-4: The positron, as a theorem. *Problem:* the *origin* of the twin is no longer owed — it is imported at theorem grade in Part V (T-P5-A/B/C and the fermionic factorization T-P5-C2 of GG-P5-CPT). What remains owed is exactly one step: nothing in this paper distinguishes the electron from the positron except readout orientation, and the CPT mirror of every statement of Part III should follow from the bulk spinor structure (Eq. 6) applied to the conjugate readout. *Why it matters:* the same-basin reading is the one interpretive row left in the Q6 status table (Table 3); its promotion would close the sixth question at theorem grade end to end. *What counts as a solution:* a short companion statement — conjugate winding, same basin level, same absence of exit gates — promoted from §22 to a proved corollary of A2's quaternionic structure and A8's projection, composing T-P5-C2 with GFF-ST7.

D-P3-5: Sharpening the m_e residual. *Problem:* the codebook reproduces m_e at 1.9×10^{-4}; CODATA knows it at 3×10^{-10}. Six orders of magnitude of unexplained residual stand between the QD layer and the data. *Why it matters:* this is the paper's most exposed number (§41, Objection 5): the framework's wager is that the residual is the next QD order, not a breakdown. *What counts as a solution:* an upstream (GG-A9-SM) derivation of the next correction layer with a declared precision target — agreement at 10^{-5} would be a spectacular postdiction audit; a derived next order that *moves away* from CODATA would be a quiet form of F4, and we say so now so that it cannot be reframed later.

D-P3-6: Pointlikeness for the non-ground basins. *Problem:* Theorem 29.2 is stated for the electron; the muon and tau occupy basins of the same non-spatial landscape, and the same argument should give $F \equiv 1$ for them too. *Why it matters:* muon substructure searches are an active experimental program, and the framework should say in advance what it owes there. *What counts as a solution:* a one-page corollary extending Proposition 27.1 and Lemma 29.1 basin-by-basin — with the one new subtlety (the non-ground basins' finite lifetimes and gate couplings) handled explicitly rather than waved through.

D-P3-7: The gravitational form factors. *Problem:* this paper's $F \equiv 1$ concerns the electromagnetic structural form factor. The electron also has energy-momentum (gravitational) form factors; does the non-spatial-structure argument extend? *Why it matters:* a framework that derives Newton and Coulomb from one geometry (GG-A9-SM's forces section) should speak with one voice about the matter side of both. *What counts as a solution:* the analogue of Appendix F for the stress-tensor vertex — including an honest treatment of what "mass as basin level" implies for the D-term, where we genuinely do not yet know the answer.

These seven problems are the paper's to-do list, and F1–F5 are its standing offer to be wrong. After all, a review that aims to clear the reader's mind owes the reader one thing above all: an exact map of where the clearing ends.

41 Common objections and responses

We close the Discussion with the objections a critical reader should raise — the strongest versions we could construct, including several sharpened by the hostile-referee pass this paper underwent before shipping. The format follows the cohort convention (GG-A2-GG6's closing objections section): each objection is stated at full force, and each response begins by conceding whatever the objection gets right.

Objection 1 (O-P3-1): "QFT already explains identity; this paper redescribes it." The field answer is real and exact (§11.1), and any account that pretended otherwise would be wrong. But the objection conflates two questions. QFT explains why excitations of one field are alike; it cannot say why *this* field exists with *these* values — those are free inputs, and "free input" is not an explanation but a place where explanation stops. The present paper derives the inputs: y_e from five integers, charge from winding, spin-$\frac{1}{2}$ from the bulk group. A reader who holds that deriving the content of identity adds nothing to asserting its form is invited to apply the same standard to the hydrogen atom: Bohr did not "redescribe" Balmer.

Objection 2 (O-P3-2): "Pointlike by axiom — AX-1 assumes what Q4 asks." Partially right, and the paper says so before the objector can (Appendix F, Step 2, first Remark). AX-1 contributes point-attachment of observables — an axiomatic input, exactly as stated. What AX-1 alone cannot do is dissolve the self-energy crisis (the SM's point electron still needs renormalization's subtraction) or exclude hidden compositeness ("by construction" is silent about deeper scales — that is why compositeness searches exist). The new content is the conjunction: Proposition 27.1 makes point-locality *consistent* (the structure exists, elsewhere than space), and Lemma 29.1 makes it *permanent* (no scale hides in the readout). An axiom plus two theorems that make the axiom tenable is not the axiom alone.

Objection 3 (O-P3-3): "Theorems 'within GDOS' just relocate the mystery into your axioms." We accept the criticism in the form stated: every theorem in this paper is conditional on the declared axiom system, and a reader who rejects the constitution receives conditionals.

Two replies. First, relocation *with compression* is what explanation is: five independent mysteries became consequences of one axiom system that also derives the Standard-Model parameter sheet, the cosmological inventory, and the family count elsewhere in the cohort — the mystery count went down, sharply. Second, the axioms are not freely adjustable refuges: AX-1 through AX-4 are fixed cohort-wide, and this paper added no axiom of its own — its one new assumption-shaped object (RL) was *derived*, and its honest residue is a formalization step (D-P3-1), not a new postulate.

Objection 4 (O-P3-4): "The coupling clause and an open integrality lemma carry Q3; an axiom-plus-lemma cannot close a century-old question." Correct as stated, and the paper never claims otherwise: Q3's upper bound is conditional on the coupling clause and L-INT at every layer, including the abstract — though the residue is now one topological check (R-INT), discharged on the benchmark background in GG-P2-N3's Appendix H, with two obstruction theorems showing why nothing weaker can replace the clause. What the objection underweights is what is *unconditional*: the lower bound (given observed CP violation), the basin ontology, the codebook cross-check at four significant figures, and the dynamical reading. The honest position is that "why exactly three" is nine-tenths closed with the last tenth named — which is a different epistemic state from "open," and a century better than "who ordered that?"

Objection 5 (O-P3-5): "The m_e residual is a $10^5\sigma$ discrepancy — the codebook is already falsified." This is the sharpest arithmetic objection available, and we state it with full force: CODATA knows m_e to 3×10^{-10}; the codebook misses by 1.9×10^{-4}; measured against experimental uncertainty, that is astronomically many standard deviations. The response is about what the codebook claims to be: a *first-order-plus-QD* structural calculation with a declared precision of its own, not a prediction with experimental-grade error bars. The correct comparison is between layers: first-order misses by $\sim 10^{-3}$; the QD layer improves this to 1.9×10^{-4}; the wager (D-P3-5) is that the next layer continues the pattern. The framework is falsified at this number only if its declared precision is violated — which F4 registers — or if the layer-by-layer convergence breaks, which we have committed in advance to report as failure rather than re-parameterize.

Objection 6 (O-P3-6): "The open-system readings are unfalsifiable decoration — why are they in a physics paper?" Honestly stated as readings rather than results, priced so in the text — and, in one case, corrected: this paper's earlier tilted-landscape reading of spatial drift was withdrawn as mis-sectored (§34), which is the INT discipline working exactly as designed. It is included for the same reason interpretations of quantum mechanics appear in serious papers: Q5's ontological kernel is a real question, the formalism's silence on it is a real silence, and a framework that *can* formulate an answer should display it with its status tag rather than suppress it. Nothing downstream depends on it; deleting Reading 34.1 would cost the paper one insight and zero theorems — which is exactly what the INT tag tells the reader.

Objection 7 (O-P3-7): "Calling a dimension 'scale' is relabeling; any compact direction can be renamed." The difference is in the symmetry algebra and in the observables, not the vocabulary. A spatial circle has a radius (a continuous dial), translations along it generate momenta, and its existence produces a Kaluza–Klein tower and form-factor structure at $\hbar/R$ — the experimental signature of *space*. The GG-6 directions have no dials (dimensionless r with integer endpoint; $G_{\theta\theta} = 1$), their generators are a dilatation and a compact charge, and they produce *no* tower — the absence being P2/F2's testable content (§F.5). A relabeling with different observable consequences is not a relabeling.

Objection 8 (O-P3-8): "A unique ground state seems to forbid the positron — yet positrons exist." A fair reading of an imprecise phrase, and the precision matters: the GGA is unique *per stratum and per readout orientation*. The positron is the conjugate readout of the same basin — same level (mass), opposite winding eigenvalue (charge) — exactly as CPT requires; what the framework forbids is a *second basin*, not a second orientation. This is no longer a fence but a chapter: Part V houses it as the sixth question, with the origin of the twin imported at theorem grade from GG-P5-CPT and the same-basin reading priced in Table 3. The spinor-level promotion remains owed and registered (D-P3-4); the observation that PET scanners work is not in tension with this paper — it is Part V's daily-life anchor.

Objection 9 (O-P3-9): " 'No exit gate' must secretly violate the completeness of QFT's decay analysis — in the SM the electron is stable for a reason already." It is, and the paper keeps the reason: within the framework the standard argument (charge conservation + lightest charged state) survives intact, with its premise — the derived U(1) and the spectrum termination — now supplied rather than assumed (§13.2). The no-exit-gate statement does not compete with the SM argument; it explains the SM argument's premises, and adds one thing the SM cannot: the forbiddance of charge-violating channels is structural, not statistical, which is why P1 covers the Borexino channel at all.

Objection 10 (O-P3-10): "These are pseudo-questions — 'why' lies outside physics." The century's working position, engaged at length in §43, and not a foolish one: insisting on "why" without a deeper layer yields numerology, and the discipline was right to refuse. But the demarcation is empirical, not principled: a why-question becomes physics the moment a framework exists in which its answer is a theorem with kill criteria. That moment is what this paper claims has arrived for these six questions. The reader need not agree that the claim succeeds; the reader can no longer say the questions are unanswerable *in kind* — Part VIII lists the experiments.

Objection 11 (O-P3-11): "Calling a_e 'pure QED dressing' is wrong — the SM value includes hadronic and electroweak loops." Acknowledged, and corrected where it appeared: the accurate statement is *Standard-Model* dressing of a structureless point — QED to high order plus the small hadronic and weak terms, all of them vacuum and probe physics rather than electron structure (§39, P3). The paper's claim concerns the structural contribution: exactly zero, at every order, forever. The objection improves the paper's wording and leaves its content unchanged — the most useful kind.

Objection 12 (O-P3-12): "Basins, gates, landscapes — metaphors that explain everything explain nothing." The vocabulary is metaphorical; the objects are not. The landscape is a Morse function on a specified stratum; the basins carry indices (0, 2, 4), levels (the measured masses), and tolls (2π, π — actions in measured lifetime exponents); the gate count is the family number, checked against LEP. Every metaphor in this paper has a number attached, and the numbers have falsifiers (F1–F5). The fair test of "explains everything" is whether anything could refute it; §39 is the refusal of that charge in advance.

Objection 13 (O-P3-13): "A single-author preprint cohort, self-citing its own theorems — why should anyone trust this?" The honest answer is: no one should *trust* it, and the paper is engineered so that no one has to. Every load-bearing step carries a status tag; every import names its source and its fences; the arithmetic reproduces programmatically; the references were verified against the literature; the kill criteria are pre-registered; and the intended reader (§1) is invited to audit, not believe. Single-author programs have been right before and wrong before; the only protection either way is exactly the discipline of exposure this cohort practices. The sociology is a reason for caution; it is not an argument, and the paper asks to be met with arguments.

Objection 14 (O-P3-14): "'No substructure ever' is unfalsifiable — you can never verify 'ever'." The objection inverts Popper. A universal negative can never be *verified*; it is for precisely that reason the most *falsifiable* kind of statement in science — refutable by one event, at any energy, in any decade, by any experiment, with no parameter to absorb the blow. Compare the alternatives honestly: a compositeness model with floating Λ is the unfalsifiable party here, retreating one decade per decade. This paper's claim stands still and waits.

Objection 15 (O-P3-15): "Lemma RL's 'derivation' is a verbal argument, not a proof." The strongest form of the paper's most important objection, and the response has three parts. First, the derivation is not verbal: it is a two-branch case analysis on the support of the registration kernel, each branch closed by an explicit constitutional clause (spacelike support barred by AX-1's statement; causal support scale-confined by the equal-time-slice argument), with the scope stated. Second, its one genuinely informal step is named, isolated, and registered (D-P3-1) — the difference between a physicist's argument with a declared gap and hand-waving is precisely that the gap has a name and a falsifier (F5). Third, the cohort's record on such steps is the relevant evidence: every previously declared gap in this lineage was either closed or honestly reported as open in the successor paper, never silently absorbed. We accept the demand the objection encodes — D-P3-1 is the paper's principal debt — and we decline the implication that naming a debt is the same as defaulting on it.

Fifteen objections, fifteen responses, several conceding real ground — which is how it should be. After all, a paper that can state its opponents' best arguments more sharply than they would is a paper that has earned its conclusions twice.

42 Part VIII in plain English: what has been shown, what it is worth, and what would kill it

The technical work is finished and this Part steps back from it. It states in plain terms what has been established for each of the six questions and what each answer buys; it locates the result against every prior approach known to us, and against the two dominant frameworks of beyond-Standard-Model physics; it consolidates the predictions into a falsification program; and it sets out the open problems at their full length rather than in a closing sentence.

The ordering is deliberate. The positive case comes first and the objections come last, so that the defensive material is read after the argument rather than instead of it. The objections are ours, written to be the strongest a critical reader would raise, and where the honest answer is "not yet" it is given as that.

The comparison with strings and supersymmetry is the section a skeptical reader should turn to first. It is written to be checkable rather than persuasive: three frameworks, the same questions, and a row recording what each one requires to exist that has not yet been seen. That row is the axis along which any of the three — this one included — can be retired.

Part IX
Conclusions: The Century, the Closing, and the Fifty-Year Arc

Why the questions waited, what has been answered, and a word to the wider reader

43 Why a century? The structural reasons the questions stayed open

It would be easy — and wrong — to read this paper as an indictment of twentieth-century physics: *five obvious questions, a hundred years, no answer; what was everyone doing?* What everyone was doing was, by any standard, the most successful science in human history, and the century's silence on Q1–Q5 was not blindness — and its premature confidence on Q6, answered formally in 1931 and understood structurally only now, was the same structure wearing the opposite mask. It was structural. It is worth stating the structure plainly, both because the questions deserve an account of their own neglect and because the account explains what had to change before they could be answered.

First, **the questions had no home**. Q1 lived in the foundations of quantum field theory, Q2 in particle phenomenology, Q3 in flavor physics, Q4 in renormalization theory, Q5 — when it was admitted at all — in the philosophy of physics. Five thriving subfields, five filing cabinets; and the observation that the six questions might be one question belonged to none of them. A conjunction has no natural referee. The literature is full of excellent partial treatments of each fragment; the present paper's bibliography cites the best of them; what the century never produced is a paper whose *subject* is the conjunction — because no framework made the conjunction a single object that a paper could be about.

Second, **the deepest question was answered by grammar, and grammar ends conversations**. Quantum field theory does explain why all electrons are alike: they are excitations of one field. The answer is correct, and it is the kind of answer that stops further asking — not because it satisfies, but because it relocates. Once sameness is the grammar of the formalism, "why this field, with these values?" sounds like a question about the formalism rather than about the world, and physicists are rightly wary of those. The question did not die; it was reclassified — filed under metaphysics, where working physicists do not browse. Mermin's famous summary of the prevailing attitude — "shut up and calculate" (Mermin, 1989) — was coined about quantum foundations, and it applied with full force here: the calculation worked, so the conversation moved on.

Third, **the success trap**. The classical electron's self-energy crisis was a genuine emergency — it broke theories and careers — and renormalization resolved the emergency without answering the question: the infinity was not explained but absorbed, the point-like ontology kept by construction.

Then QED proceeded to agree with experiment at parts in 10^{12}, and a discipline cannot easily keep treating as open a question whose evasion is confirmed to twelve digits. Q4 was not answered; it was *outperformed*. The radius bounds shrank, the precision grew, and "why is it a point, and why does that cost nothing?" came to feel like ingratitude.

Fourth, **the inputs culture**. The Standard Model institutionalized its free parameters: m_e and α are entries in a data book, maintained with magnificent care, and the professional slot for "why these values?" simply did not exist — the available answers were anthropics or numerology, and serious people rightly avoided both. A culture in which values are measured rather than derived has no failure mode for Q1's second half; it has only a silence where the question would go. What was missing was not curiosity but a framework in which a value could be a theorem — because only against derived values can "why these?" even be wrong.

Fifth, and most structurally, **the closed-system blind spot**. The answer this paper assembles is built from the vocabulary of descent: landscapes, basins, gates, relaxation, a ground state that is *reached*. None of these are concepts of closed-system fundamental physics. A unitary, time-reversible, closed dynamics has no descent — nothing relaxes, nothing is spent, nothing halts (the exact open-system equations that do descend (Lindblad, 1976) were filed under applied decoherence, not foundations) — and so the very nouns needed to *state* the answer were absent from the fundamental level for a century, quarantined in statistical mechanics and chemistry as "emergent" talk. GG-P2-N3's methodological reflection (Arisaka, 2026, P2-N3) makes the argument in full for the family number: closed-system methods produce admissibility conditions, never upper bounds; the budget that stops the ladder at three is an open-system resource. The same diagnosis covers all six questions at once. Ground-state-ness is an open-system fact. A physics that treats openness as an approximation cannot say what the electron is, for the same reason a grammar with no past tense cannot say what happened.

None of this required anyone to be wrong. The deferral was honest discipline: without a layer beneath the inputs, insisting on "why" yields numerology, and the century's refusal to indulge it protected the subject's integrity. The cost was only that the questions aged into furniture — present in every room of physics, sat upon daily, and no longer seen. What changed, on the present account, is not that someone finally thought harder; it is that two ontological commitments shifted at once. The extra structure of the world was allowed to be *non-spatial* — a scale direction and a phase direction, rather than more space — and the fundamental dynamics was allowed to be *open* — a descent, rather than a reversible flow. On those two commitments the six questions stop being six metaphysical leftovers and become one geometric statement with a status table and kill criteria. Whether the statement is *true* is for experiment — Part VIII says exactly where to shoot. That it is *askable* is already the century's lesson: questions do not die of difficulty; they die of having no language, and they revive the moment one exists.

44 The view from the last page: four oldest facts, two formulas, one geometry

Before the plain-language close, we look once, panoramically, at where Part VII has actually left the reader — at a single table that this paper has earned the right to draw only on its final pages, because every cell of it is now a derived statement. Consider the four oldest dynamical facts about matter, the four that every laboratory and every sky exhibits: charges attract and repel (Maxwell, 1865); masses fall (Newton, 1687); accelerated charges radiate (Larmor, 1897); orbiting masses spiral inward (Hulse & Taylor, 1975). The century inherited these as four separate literatures. In the present framework they are generated — not assembled — by two derived dichotomies. The *columns* are the two curvature slices of the one composite connection that AX-2 declares to be the world's whole structural content: the gauge slice carried by the phase dimension, the metric slice carried by the scale dimension. The *rows* are the two dynamical regimes of the one constitution: the closed, conservative dynamics of the bulk (GGEP), and the open, dissipative dynamics of the boundary reduction (OGGEP → GDOS → GRIP-In). And each row is literally *one equation read twice.*

Row 1 is the unified equation of motion, Eq. (12). Its right-hand side, read alone, is cell (1a): the local U(1) invariance of the phase fiber forces the connection A_μ, minimal coupling is the complete gauge-sector coupling AX-2 permits, and the static Green's function delivers Coulomb's law (§33.1, Chain B). Its left-hand side, read alone, is cell (1b): the scale-profile reduction along the scale dimension delivers M_{Pl}^2, Einstein's equation, Newton's law, and $F = ma$ as geodesic bookkeeping (Chain A). One trajectory, two curvatures, no force postulated. Row 2 is the canonical GDOS current — the gradient-plus-circulation-plus-noise decomposition whose radiative deployment is GG-A5-GDOS's Part VI completion and quantitative closure (Arisaka, 2026, A5-GDOS). Its gauge-slice reading is cell (2a): synchrotron damping as the gradient sector, with the mobility derived in closed form and carrying Larmor's coefficient exactly, halting at the equilibrium emittance whose universal constant is measured in every electron storage ring. Its metric-slice reading is cell (2b): the binary inspiral as the same gradient sector on the orbital elements, with the mobility carrying Peters' coefficient exactly, halting at nothing — the merger — with five decades of binary-pulsar timing (Hulse & Taylor, 1975) and the directly recorded waveforms (Abbott et al., 2016) as its anchors. Table 7 sets the four cells out.

Two refinements make the table exact rather than evocative. *First, the row assignment is an energetics statement, not a field-type statement.* Both fields populate both rows in general: a charge accelerated by an electric field also radiates, and a charge in a magnetic field is also conservatively bent. What is exactly true is that $q\,\vec{v} \times \vec{B}$ does no work, so under a pure magnetic field the *entire* energy budget is radiative — the magnetic cell is nature's clean preparation of Row 2, which is precisely why the synchrotron is the golden case — while the static electric field does work conservatively, making the Coulomb cell the clean preparation of Row 1. The gravity column, elegantly, separates its rows not by field type but by *timescale*: the same binary is cell (1b) on any single orbit and cell (2b) secularly. *Second, the two non-spatial dimensions divide the labor of Row 2 exactly as §34's two-sector discipline requires.* The emitted quantum is gauge-sector; what

Table 7: The four oldest dynamical facts as one geometry: columns are the two curvature slices of the composite connection; rows are the closed (GGEP) and open (OGGEP/GDOS) regimes. Row 1 is one equation read twice (Eq. 12); Row 2 is one current read twice (GG-A5-GDOS's canonical GDOS decomposition, radiative closure included (Arisaka, 2026, A5-GDOS)). Every cell carries measured numbers at accessible energies.

	Gauge slice (S^1_θ, 6th)	**Metric slice (I_r scale profile, 5th)**
Closed (GGEP): one equation, Eq. (12)	(1a) Coulomb's law; the Lorentz force; α derived, charge quantized	(1b) Newton's law; $F = ma$ as geodesics; G_N from the scale-profile integral
Open (OGGEP/GDOS): one current, one ledger	(2a) synchrotron damping; mobility = Larmor-exact; equilibrium emittance measured	(2b) binary inspiral; mobility = Peters-exact; Hulse–Taylor, LIGO

belongs to the scale dimension is not the emission but the *openness* — the OGGEP reduction whose depth coordinate is the scale direction, and which makes the loss irreversible. The sentence to keep is this: *the sixth dimension supplies what is emitted; the fifth dimension supplies why it cannot come back.* Geometrizing electromagnetism required both: the conservative half of QED is phase geometry (Row 1), the dissipative half is scale-structured openness (Row 2), and neither dimension alone completes the geometrization — the pair does.

The table also settles a piece of history. Weyl's 1918 attempt geometrized electromagnetism on the *scale* direction (Weyl, 1918) and failed to Einstein's objection that histories would imprint on atomic spectra; the 1929 repair moved gauge to the *phase* (Weyl, 1929). The present framework diagnoses the episode rather than merely surviving it: both directions are real, non-spatial, and employed — the phase got electromagnetism's conservative half; the scale got gravity's strength, the renormalization flow, and the arrow of time. Weyl was not wrong that scale is geometric; he assigned it the wrong force. Likewise Kaluza–Klein (Kaluza, 1921; Klein, 1926) was not wrong that a fifth dimension unifies; it was wrong that the dimension is spatial — which is where the towers, the moduli, and the invisibility problems came from. And it locates the contrast that §38 drew at full length: faced with two great theories, there are exactly two unification strategies — make gravity behave like a gauge field theory (*quantize gravity*, moving the unification up to the Planck scale, where no number has ever been measured), or make the gauge force behave like gravity (*geometrize the gauge force*, moving it down into the laboratory). The twentieth century took the first road almost unanimously; Einstein took the second and failed for a reason the next section names. The inventory of the second road is now the table above: cell (1a) carries α and charge quantization, cell (1b) carries G_N, cell (2a) carries the storage-ring constants that run every light source on Earth, cell (2b) carries the pulsar timing and the recorded waveforms — four cells, four empirically saturated regimes, no adjustable coefficient anywhere in the table. We state the status of this section with the same care as everywhere else: every formula in the table is owned where it was derived (Parts VI–VII; GG-A5-GDOS's Part VI and closure); the judgment that this constitutes the *deeper* unification is the program's reading of its own results, and we price it as such. What is theorem-grade is the generated structure — two dichotomies, two master formulas, four cells — and the numbers.

45 The century completed: openness as the missing half of Einstein's dream

Section 43 gave five structural reasons the questions waited; its fifth — the closed-system blind spot — is deeper than the other four, deep enough to rewrite the standard history of the unification program, and this paper should say so plainly before it closes. The standard telling of why Einstein's unified-field program failed is that he ignored quantum mechanics. The precise telling is that he asked a *closed* theory to do an *open* system's jobs. The quantum, the arrow of time, measurement, dissipation, decay — every phenomenon that defeated the geometrizers of the 1920s through the 1950s is a boundary phenomenon, a property of what a reduced observer registers, not of what the bulk is. Einstein kept trying to build those into the geometry itself, where they cannot live; the Copenhagen settlement built a calculus for the boundary and declared the bulk meaningless. The century-long stalemate was two camps each insisting that its layer was the only layer. The constitutional split of this program — a closed geometric bulk under GGEP, a derived open reduction under OGGEP — is, in that sense, the treaty: *Einstein was right about the bulk* — it is closed, deterministic, geometric; *Bohr was right about the boundary* — it is probabilistic, irreversible, and cannot help but play dice. The dice are what determinism looks like through a partial trace. God does not play dice in the bulk; the boundary has no choice.

There is also a hard historical reason the completion took the century, and it acquits everyone involved: *the mathematics of openness did not exist.* The influence functional — the exact form of a traced-out sector — is 1963 (Feynman & Vernon, 1963), eight years after Einstein's death. The general open-system generator is 1976 (Lindblad, 1976). The gradient-flow formulation of dissipative dynamics — the very language in which the descent of this paper's landscapes is written — matured only from 1998 onward (Jordan, Kinderlehrer & Otto, 1998). Einstein failed not only for want of the right geometry but for want of tools that had not been invented; the second half of his dream was mathematically inaccessible in his lifetime. What the present program adds is the recognition that this body of mathematics is not a phenomenological toolkit for quantum optics and chemistry but constitutional physics — the derived law of what any boundary observer sees (Arisaka, 2026, A5-GDOS; Arisaka, 2026, A6-GRIP).

The author's thesis here — and the experience of assembling this paper has confirmed it at every turn — is that *any system in nature is an open system*, and that this sentence has an exact formal expression which inverts the textbook hierarchy. In the traditional ordering, closed mechanics is fundamental and dissipation is a correction bolted on. In the structure actually derived, it is the reverse: the closed, conservative physics of Row 1 is a *sub-sector* of the open physics of Row 2 — the unified equation of motion is the divergence-free circulation piece of the canonical GDOS current, the part that survives when nothing is shed (GG-A5-GDOS's closure derives exactly this: the conservative orbit *is* the circulation sector, by the angle average of the exact reduced dynamics). $F = ma$ is what the open current does on its silent sector. Closed physics is the special case; openness is the law. A century of mechanics was taught in the opposite order, and that — more than any single equation — is the inversion this program asks its reader to make.

A resonance of dates belongs in the record. This paper is completed in 2026 — exactly one century after the boundary calculus was written down without a derivation: Schrödinger's equation (Schrödinger, 1926) and Born's rule (Born, 1926) are both 1926. A hundred years later, the companion papers derive the Born rule as a theorem of the boundary reduction (Arisaka, 2026, A8-QM), and the same reduction, deployed in this paper's Part VII, hands back Larmor's and Peters' coefficients and a storage-ring constant measured to four digits. The centennial framing is not decoration; it is the actual shape of the history.

One word of method, because the fifty-year questions deserve a claim that cannot be embarrassed. "Paradigm shift" is, in Kuhn's own terms (Kuhn, 1962), a verdict the community renders after a framework dissolves standing anomalies and survives its falsifiers; it is not a thing a paper can declare, only a thing a paper can *qualify for*. What may be written down today, defensibly, is this: the conceptual inversion is complete and explicit; the anomalies it dissolves are named — the measurement problem (dissolved by the always-on OGGEP projection, GG-A5-GDOS §23), the radiation-reaction pathologies (Dirac, 1938), the six century-old questions of this paper, the quantize-gravity impasse — and the kill criteria are pre-registered (Part VIII, §39), with every imported fence declared. A paradigm shift with declared falsifiers is a scientific claim; without them it is a mood. This program has the falsifiers, and the sentence should never be said without them attached.

Last, the dream itself, in Einstein's own three clauses. He wanted the forces unified: that is Table 7, the two curvatures of one connection, statics, dynamics, and now dissipation. He wanted the bulk lawful: that is the treaty above — determinism upstairs, derived dice downstairs. And he wanted matter itself to be field-theoretic — "a completely field-theoretic description of matter," particles as aspects of the geometry rather than foreign bodies placed in it. That third clause is this paper: the electron as the unique ground state of the geometry, its mass a basin level, its charge a winding, its spin a double-cover tag, no body anywhere. The five questions the author has carried for fifty years — and the sixth, which he, like everyone, was taught to regard as solved — turn out to be the *matter clause* of the same dream — which is why their answers arrived together, from one landscape, the moment the landscape was drawn with both of its halves: the geometry that is closed, and the observation that is not. Status, one final time: this section is the program's reading of its own results — interpretive by this paper's own tags, resting on theorems owned elsewhere and on fences declared throughout; the reader who wants the load-bearing chain will find every link in Parts III–VII and the status ledger of Appendix B. The philosophy is priced exactly like everything else in this paper. That is the discipline, and we keep it to the last page.

46 Conclusions, in plain English

We close the technical portion of the paper in plain language, for the reader — physicist or not — who wants to know what was attempted here and what it would mean if it stands.

46.1 The wider view: what the six answers attempt together

This paper took the six oldest facts about the electron — everywhere identical, absolutely stable, twice copied, exactly mirrored, perfectly point-like, mysteriously responsive — and argued that they are not six facts. They are one fact seen from six directions: *at the bottom of the electron's sector of the world there is exactly one deepest basin, and the electron is what occupying it looks like.* Identity is the uniqueness of the basin; stability is the absence of any exit; the muon and tau are the two higher basins of the same landscape, and their count is the landscape's budget; the point-likeness is the statement that the basin's structure lies along directions that are not space; the positron is the same basin read in the mirror; the sensing is the electron following the same composite geometry that makes apples fall — the open-system layer adding only the arrows, radiation as it moves, descent where decay is possible (for the electron, nowhere). Around this one picture stand the companion papers of the program — the constitution that fixes the axioms, the bulk theorems, the open-system runtime, the codebook that turns geometry into the measured numbers, and the sister paper that counts the basins — each cited, none re-derived, every borrowed fence carried along visibly.

46.2 What this paper is, in one sentence

This paper is an attempt to move the electron — the first elementary particle we ever found, and the one all of chemistry, biology, and technology runs on — from the list of things physics *assumes* to the list of things physics *explains*, and to do it with every assumption named and every failure mode declared in advance.

46.3 Why this matters beyond physics

Three reasons, in widening circles. Within science: "ground state" is the single most borrowed concept physics ever lent its neighbors — chemistry's stable molecule, biology's folded protein, every discipline's notion of a configuration things settle into. If the present account is right, the loan was repayment: the concept was constitutional all along, and the electron is its charter case. For the practice of science: this paper is an experiment in a discipline of candor — strong claims held together with declared fences, status tags on every step, kill criteria published before the referees arrive. We believe ambition and honesty are not rivals, and that the fences made the thesis stronger, not weaker; readers who take nothing else from the paper are invited to take the method. And for anyone at all: the sameness of the electron is the reason the universe is *reliable* — the reason a water molecule formed twelve billion years ago is identical to one formed this morning, the reason chemistry repeats, the reason memory, inheritance, and civilization can exist in a world built of particles. And the sameness holds not only across time but across the sky: the electron in a hydrogen atom on the far side of the observable universe — in a region that, but for inflation, was never in causal contact with our own — carries the identical mass and charge, so its Balmer lines are our Balmer lines (Corollary 11.2; the cosmological statement is the *second horizon problem* of GG-A10-Cosmos). Temperature could be smoothed by contact; identity could not, and needed no smoothing — it was one attractor all along. To explain that sameness, in time and in space, is to explain why the universe can be a home rather than merely a place. The question a child asks — *why is everything made of the same stuff?* — turns out to be the deepest one in the building, and we have tried to treat it with the seriousness it always deserved.

46.4 What we hope a careful reader will take away

Three convictions, offered for audit rather than assent. *First*, that the six oldest questions about the electron are one question, and that at least one coherent, quantitative, falsifiable answer to it now exists — conditional exactly where its status table says it is conditional, and nowhere else. *Second*, that the century of silence was structural, not shameful — and therefore that its lesson points forward: where a deep question seems unanswerable, look first at what the reigning ontology cannot say, for questions die of missing language, not of difficulty. *Third*, that the questions you carried out of your first year of physics were the right questions — that noticing what the textbook does not pause on is the beginning of the work, not a distraction from it. If this framework is right, those questions now have answers you can check. If it is wrong, the kill criteria of Part VIII tell you precisely how to show it — and the authors of this program would rather be refuted sharply than believed vaguely. Either way, the questions are yours again, with interest.

After all, a universe in which every electron is the same electron is a universe that keeps its promises — and a physics that can finally say *why* has begun, at last, to keep its own.

47 The fifty-year arc

I met these five questions as a student, fifty years ago, in the form every physics student meets them: as facts so basic that the textbooks did not think to flag them as mysteries. The sixth I met differently — as a triumph: the positron, predicted by an equation. It took most of the fifty years to notice that "the equation predicts it" names a mystery rather than solving one. Every electron is the same; electrons do not decay; there are, inexplicably, three copies; the electron is a point; charges feel forces. One learns to calculate with all five before one notices that none of them has a reason. I noticed — I have never been able to un-notice — and for five decades, through a career spent mostly on other questions, these five kept their place on the private list a physicist carries of things he would like to understand before he is done.

What I did not expect, through most of those decades, is that the five would turn out to be one. The framework assembled across the companion papers of this program was not built to answer them; it was built to close the parameter sheet of the Standard Model and the inventory of the cosmos. That the same geometry, at the point where its cascade halts, should hand back the electron — identical because the ground basin is unique, stable because the ground basin has no gate, copied twice because the landscape above it holds exactly two more basins, pointlike because its structure lies along directions that are not space, responsive because to occupy a basin is to descend its tilts — was not an ambition. It was the view from the bottom of the landscape, once the landscape was drawn.

I have tried to write the paper I would have demanded as a referee at any point in those fifty years: every fragment of standard physics credited at full strength; every step that is not a theorem named as what it is; the kill criteria stated where the paper can be shot. The questions deserve that discipline. They were patient with me for fifty years; the least I owe them is a closing that cannot be embarrassed.

After all, the electron was the first elementary particle we ever found, and it may be the last one we truly understand — not because understanding came hard, but because for a century we mistook its six deepest properties for six separate facts, when they were always one fact, seen five times: at the bottom of the world there is exactly one basin, and everything ordinary that exists is what it looks like from inside.

Part X
Appendices

Abbreviations, the complete derivations for Q1–Q5 (Q6's derivation is the CPT companion's, imported in Part V), and reference material

A Summary of Abbreviations

This appendix collects the abbreviations used in the present paper, following the convention of GG-A2-GG6's Appendix A: program-defined names are rendered in *sans-serif type* so the reader can see at a glance which terms belong to the GG-Theory program proper; standard physics abbreviations imported from the wider literature are in plain uppercase Roman; mathematical objects are in roman or italic in the usual way. The canonical Dictionary of Program-Defined Acronyms — each entry with a full definition and a plain-English physics intuition — is GG-A2-GG6's Appendix B and is not duplicated here.

Table 8: Summary of abbreviations used in the present paper. Program-defined names are set in sans serif, standard physics abbreviations in plain uppercase roman, and mathematical objects in roman or italic as usual. The third column points at the paper or the section where each name is fixed, so an abbreviation met in the middle of an argument can be resolved without leaving the appendix.

Symbol	Meaning	Primary link
GG-Theory	Grand Geometric Theory, the program of this cohort	GG-A1-Constitution
GG-6	The six-dimensional bulk $\mathcal{M}_4 \times I_r \times S^1_\theta$ with geometry–gauge locking	GG-A2-GG6
AX-1 (LC)	Axiom 1: Locality and Causality, binding dynamics *and* measurement instruments	GG-A1-Constitution; §29
MSMF	Axiom 4: "Maximum Symmetry, Minimum Freedom" — no unforced structure	GG-A1-Constitution
GGEP / OGGEP	(Operational/Open) Geometry–Gauge Equivalence Principle; OGGEP is the bulk-to-boundary registration	GG-A1-Constitution, GG-A8-QM
BI-6	The modified Bianchi identity of the six-force bulk (anomaly closure)	GG-A3-BI6
OGN-5	The integer ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$, Diophantine-unique	GG-A2-GG6, Thm. 6
GU-5	The five universal constants $\{c, G_N, \hbar; k_B, Q_B\}$	GG-A4-Euclid
GDOS	Geometric Dynamics of Open Systems: the boundary law	GG-A5-GDOS
Gi-4	The four geometric pillars (TGG, CCI, GFF, GRIP)	GG-A6-GRIP
GFF	Geometric Free-energy Functional: the master landscape whose valleys are the stable boundary objects	GG-A6-GRIP

Table 8 continued from previous page

Symbol	**Meaning**	**Primary link**
GFF-ST7	Structure theorem: each stratum has a unique deepest attractor	GG-A6-GRIP
GRIP	The cascade runtime DGI $\to$ GSSB $\to$ GA	GG-A6-GRIP
GRIP-In	Fixed-landscape regime: relaxation on the landscape (drift, decay)	GG-A6-GRIP, def:GRIPin
GRIP-Out	Landscape-rebuilding regime: transient, out of equilibrium	GG-A6-GRIP, def:GRIPout
DGI	Dynamical Gauge Invariance: the symmetric top of the cascade	GG-A6-GRIP
GSSB	Geometric Spontaneous Symmetry Breaking: branch selection at saddles (the gates)	GG-A6-GRIP
GA	Geometric Attractor: any stable basin	GG-A6-GRIP
GGA	Ground Geometric Attractor: the unique deepest basin, where GRIP-In halts	GG-A6-GRIP, def:GGA; GG-A11-Origin
QD	Quantum Descent: the finite transport-correction layer of the codebook	GG-A9-SM
RL	Readout Locality: the registration map carries no 4D length scale	Lemma 29.1
I_r, S^1_θ	The two non-spatial directions: scale (RG) interval and phase circle	GG-A2-GG6; **Figure 4**
Σ_{fam}	The family-projector stratum $\mathbb{C}P^{N-1} = \mathbb{C}P^2$	GG-P2-N3, GG-A9-SM
$F(q^2)$	The structural (elastic) charge form factor	§29
J_{CKM}	The Jarlskog CP-violating invariant	GG-P2-N3; App. E
L-INT	The integrality theorem: Hopkins–Singer quantization of the descended periods, derived in GG-P2-N3 with the single topological residue R-INT (discharged on the benchmark in App. H)	GG-P2-N3, App. E, G, H
$S^{\max}_{\text{BI6}}$	The BI-6 instanton budget, 3π = the capacity theorem at $N = 3$	GG-P2-N3, T-N3-6
KK	Kaluza–Klein (spatial compactification; the contrast case)	§F.5
RS	Randall–Sundrum (warped-throat lineage)	(Randall & Sundrum, 1999)
SM / QED / QFT	Standard Model / quantum electrodynamics / quantum field theory	standard
CKM / PMNS	Quark / lepton mixing matrices	standard; GG-P2-N3
MSSM	Minimal Supersymmetric Standard Model (contrast case)	§38.3
CODATA / PDG	Standards bodies for constants / particle properties	(CODATA, 2022; Particle Data Group, 2024)
ppt	parts per trillion (10^{-12})	(Fan et al., 2023)

B Claim-status ledger

Tag vocabulary as in §3. "Location" names the companion paper and the labeled environment or section within it. Every location was verified by direct search in the cited paper rather than from memory, so each row of the ledger below can be checked the same way.

Table 9: The complete claim-status ledger. Every load-bearing step of the paper, its status tag, its verified source, and where it is consumed. This is the table to check a claim against. Every load-bearing step appears exactly once, with the tag that grades it, the place it is established — here, or in the companion that owns it — and the section of this paper that consumes it. A step that appears nowhere in this table is not load-bearing.

Load-bearing step	**Tag**	**Source location**	**Used in**
6D bulk; I_r, S^1_θ non-spatial	THM	A2, Theorem 1 (T-GG6-1)	Parts II, VI
$\mathrm{Spin}(1,5) \cong \mathrm{SL}(2,\mathbb{H})$; quaternionic Weyl doublet	THM	A2, magic-square proposition	§12.3, §28
Ledger $(1,3,5;7,35)$ unique	THM	A2, Theorem 6	§12.1
BI-6 closure	THM	A3	Part II
e derived, not primitive	THM	A4, T-Euclid-4	§12.2
GDOS runtime; O3 (Morse-positivity) open	THM/fence	A5; O3	Parts II, III
GFF-ST7 unique deepest attractor	THM	A6, GFF-ST7	Thm. 11.1
def:GGA; def:GRIPin/out	DEF	A6, labels def:GGA, def:GRIPin, def:GRIPout	Parts III, VII
T-GGA-as-Ground-State	THM	A11, Step-3 regime theorem	§11.2
Universal-identity theorem (T-A8.9 = T-QM-9)	THM	A8, theorem T-A8.9 (label thm:TA-9)	Thm. 11.1
$y_e = N/(L^3 2^{J+L+1})$	codebook	A9, label sec:lepton-mass	Eq. (3)
$m_e^{\mathrm{QD}} = 0.511097845$ MeV; $\mathcal{R}_e = 641/640$	codebook	A9, QD-completion section	Eq. (4); residual 1.9×10^{-4} declared
$\alpha^{-1}(M_Z) = 2^J$; $\alpha^{-1}(0) = 2^J + N^2$, QD-completed	codebook	A9, dyadic-closure statements	Eq. (5)
Identity section; forces section; weak as GRIP-In	THM/ doctrine	A9: identity & forces sections (by label); GRIP-In doctrine	Parts III, IV, VII

continued on the next page

Claim-status ledger, continued

Load-bearing step	**Tag**	**Source location**	**Used in**
Lepton cascade assignment (e = depth-2 GGA)	THM	A9, label sec:lepton-cascade-depth	Eq. (7)
$N \geq 3$ from CP violation	THM given EMP	P2, leg L1	§16
Coupling clause; integrality theorem L-INT	AX; THM (residue R-INT)	P2, its Axiom AX-B and L-INT; App. C, F, G	§16
No-exit-gate; reachability reading	THM (GDOS); INT	P2, §9.3; label ssec:reachability	Thm. 13.1; §16
Non-spatial support of all electron structure	THM assembly	this paper, Prop. 27.1 (from A2/A4/A9)	Part VI
Readout Locality (RL)	LEMMA from AX-1	A1, AX-1 (label ax:LC) + constitutional clarifications 2–3; this paper, Lemma 29.1	Thm. 29.2
$F(q^2) \equiv 1$ at all scales	THM (via Lemma RL; D-P3-1 registered)	this paper, Thm. 29.2 + App. F	Part VI, P2/F2
Positron = conjugate readout of the same basin (Q6)	THM (imports) + INT (named)	P5, theorems T-P5-A/B/C, T-P5-C2; this paper, Part V	Part V; D-P3-4
Open-system arrows (radiation: motion; scale-sector GRIP-In: decay)	INT (corrected)	this paper, Reading 34.1; §34	Part VII
Worldline coupling; unified equation of motion; Newton & Coulomb parallel chains	THM	A5, Part VI (digest: App. G)	Parts VI, VII
Radiative completion: orbit = circulation, damping = gradient sector; covariant kernel	THM (field-trace closure + covariant kernel); O7 Resolved	A5, radiative-completion, closure and kernel subsections + Open Problem O7	§34, App. G.5
τ_e bound; a_e; α anchors; N_ν	EMP	Borexino 2015; Fan 2023; CODATA 2022; ALEPH 2006	Parts III, VI, VIII

C Derivations for Q1: identity and the values

This appendix assembles, in one place and at first-year-graduate level, the complete derivations behind Part III. Everything here is reproduced from the parent papers with citation — chiefly GG-A9-SM's charged-lepton codebook sections and GG-A2-GG6's group theory — so that the student can digest the material on the spot; nothing is new, and nothing is abbreviated past the point of checkability.

C.1 The uniqueness statement: GGA and GFF-ST7

The landscape vocabulary is fixed by GG-A6-GRIP (Arisaka, 2026, A6-GRIP). The GFF is a Morse functional on each boundary stratum; its index-0 critical points (basins) are the Geometric Attractors (GA); among them, def:GGA names

$$\mathsf{GGA}(\Sigma) \;=\; \arg\min_{x\in\Sigma} F_{\mathrm{GFF}}(x), \tag{13}$$

and the structure theorem GFF-ST7 asserts that the minimizer is unique per stratum: a stratum, like a molecule, has exactly one ground state. The regime theorem T-GGA-as-Ground-State of GG-A11-Origin (Arisaka, 2026, A11-Origin) adds that the cascade *output* is this ground state — the descent does not strand permanently in a way station (within a stratum; the way stations are the metastable generations of Appendix D). Identity-as-sameness is then a two-line argument, which is Theorem 11.1 of the main text: all electrons are readouts of one attractor (uniqueness: GFF-ST7); a readout has no degrees of freedom beyond the attractor's data (universal-identity theorem, GG-A8-QM T-A8.9 (Arisaka, 2026, A8-QM)); hence no two electrons can differ. The honest conditioning — GDOS-internal status; the O3 note — is stated in §11.2 and not repeated here.

C.2 The dyadic charged-lepton codebook

We now reproduce the codebook derivation from GG-A9-SM's charged-lepton sections (Arisaka, 2026, A9-SM), with its own reasoning intact.

Step 1: why the lepton sector is dyadic at first order. The compact circle S^1_θ supports the Abelian holonomy and the Wilson-line Higgs, but a field pays a nontrivial *angular* suppression at first order only if its chirality or charge assignment distinguishes different angular branches. The color-singlet charged leptons are the most economical sector in this respect: their first-order family hierarchy carries zero winding,

$$w_e = w_\mu = w_\tau = 0, \tag{14}$$

so their hierarchy is *dyadic before it is angular* — they are separated not by compact monodromy but by how deeply the boundary projector must resolve their profiles (GG-A9-SM, "why the charged-lepton sector is purely dyadic"). The angular cascade is reserved for the quarks and plays no role here.

Step 2: the three Yukawa codes. The shortest charged-lepton codebook compatible with the OGN-5 ledger $(M, N, L; J, K) = (1, 3, 5; 7, 35)$ and the required family order is (Arisaka, 2026, A9-SM):

$$
\begin{aligned}
y_\tau^{(1)} &= \frac{NJ}{2^{\,J+N+1}} = \frac{21}{2^{11}} = \frac{21}{2048}, \\
y_\mu^{(1)} &= \frac{L}{2^{\,J+L+1}} = \frac{5}{2^{13}} = \frac{5}{8192}, \\
y_e^{(1)} &= \frac{N}{L^3\, 2^{\,J+L+1}} = \frac{3}{5^3 \cdot 2^{13}} = \frac{3}{1\,024\,000}.
\end{aligned}
\tag{15}
$$

The codes are explained, not merely displayed, in GG-A9-SM; we reproduce the reasoning. For the *tau*: the third-family lepton is the least suppressed; the largest admissible numerator available without a new free integer is $NJ = 21$ (family triplicity times the dyadic closure index), and the mildest dyadic depth reflecting both the neutral closure J and the triplicity N is $J + N + 1 = 11$. For the *muon*: one resolution layer deeper — the depth steps from the triplicity index to the weak-projection index, $J + L + 1 = 13$, with the single ledger integer L as numerator. For the *electron*: the lightest mode pays, in addition to the same depth 2^{J+L+1}, the *triple boundary re-projection*: each weak projection contributes a factor $1/L = 1/5$, and three successive projections give L^{-3}; the numerator returns to N because, by the time the lightest mode is reached, the dominant structure is no longer the dyadic closure but the persistence of family triplicity through the three projections. Hence

$$
y_e^{(1)} = \frac{N}{L^3\, 2^{\,J+L+1}} = \frac{3}{5^3 \cdot 2^{13}}, \tag{16}
$$

which is Eq. (3) of the main text.

Step 3: first-order masses. With the Dirac mass relation $m = y\, v/\sqrt{2}$ and the independently derived Higgs vacuum value $v^{(1)} = 246.331354$ GeV (GG-A9-SM's Wilson–Hosotani theorem; no lepton mass is an input anywhere in this chain), the codebook gives

$$
\begin{aligned}
m_\tau^{(1)} &= \frac{v^{(1)}}{\sqrt{2}}\,\frac{21}{2048} = 1.78605 \text{ GeV}, \\
m_\mu^{(1)} &= \frac{v^{(1)}}{\sqrt{2}}\,\frac{5}{8192} = 106.3126 \text{ MeV}, \\
m_e^{(1)} &= \frac{v^{(1)}}{\sqrt{2}}\,\frac{3}{1024000} = 0.5103005 \text{ MeV}.
\end{aligned}
\tag{17}
$$

The exact first-order ratios are pure ledger arithmetic,

$$
\frac{m_\tau^{(1)}}{m_\mu^{(1)}} = \frac{NJ}{L}\, 2^{\,L-N} = \frac{84}{5} = 16.8, \qquad \frac{m_\mu^{(1)}}{m_e^{(1)}} = \frac{L^4}{N} = \frac{625}{3} = 208.33\ldots, \tag{18}
$$

against the measured 16.817 and 206.768: agreement at the 10^{-3} and 8×10^{-3} level *before* any correction layer. The student should pause on what Eq. (18) asserts: two mass ratios that the Standard Model carries as free inputs are here ratios of small integers and powers of two.

Step 4: the QD completion. The first-order codebook is the rigid skeleton, not the final low-energy value; the finite QD (Quantum-Descent) transport from the idealized seam to the comparison convention is encoded by the common denominator

$$2^J L = 2^7 \cdot 5 = 640, \tag{19}$$

recognized upstream as a Hopkins–Singer descent integrality coefficient on $\mathbb{C}P^2$ (Arisaka, 2026, A9-SM). The shortest allowed rational closures are

$$\mathcal{R}_\tau = 1 - \frac{N}{2^J L} = \frac{637}{640}, \qquad \mathcal{R}_\mu = 1 - \frac{L-M}{2^J L} = \frac{159}{160}, \qquad \mathcal{R}_e = 1 + \frac{M}{2^J L} = \frac{641}{640}, \tag{20}$$

giving the transport-corrected masses $m_\ell^{\mathrm{QD}} = \mathcal{R}_\ell \, m_\ell^{(1)}$:

$$m_\tau^{\mathrm{QD}} = 1.777680 \text{ GeV}, \qquad m_\mu^{\mathrm{QD}} = 105.64815 \text{ MeV}, \qquad m_e^{\mathrm{QD}} = 0.511097845 \text{ MeV}. \tag{21}$$

The physical meaning (GG-A9-SM): the tau shifts slightly down because the least-suppressed mode still leaks into neighboring dyadic cells; the muon shifts down by more, sitting one resolution layer deeper; the electron shifts *up* because, after the triple L^{-3} suppression, the leading correction is a minimal recovery of one boundary cell rather than a further loss. Comparison with CODATA $m_e = 0.51099895069(16)$ MeV (CODATA, 2022) gives the declared residual 1.9×10^{-4} of §12.1 — the paper's most exposed number (D-P3-5), displayed rather than hidden.

C.3 Charge: quantization and the value of α

Charge quantization is topological: the electron's charge is the eigenvalue of the fixed, integer-normalized $\mathrm{U}(1)_{\mathrm{EM}}$ generator (the commutant of the selected Wilson–Hosotani vacuum) on the unique stable cascade leg — an integer times one unit, with no continuum available (GG-A9-SM; §12.2). The *strength* is the dyadic-closure attractor coordinate

$$\alpha^{-1}(M_Z) = 2^J = 128 \tag{22}$$

(GG-A9-SM's electromagnetic dyadic-closure theorem). The first QD correction is the minimal dyadic self-contraction allowed by the triplicity sector, N^2:

$$\alpha^{-1}(M_Z)^{\mathrm{QD}} = 2^J - \frac{N^2}{2^J} = 128 - \frac{9}{128} = 127.9296875, \tag{23}$$

matching the PDG running value 127.930 ± 0.008 to measurement precision (Arisaka, 2026, A9-SM; Particle Data Group, 2024). At zero momentum the same integers give

$$\alpha^{-1}(0) = 2^J + N^2 = 137.0, \tag{24}$$

with the QD-completed prediction matching CODATA's 137.036, as GG-A9-SM reports (CODATA, 2022). Finally, the elementary charge itself is not primitive: with α derived and the GU-5 constants in hand, T-Euclid-4 of GG-A4-Euclid (Arisaka, 2026, A4-Euclid) reads e off as $e = \sqrt{4\pi\epsilon_0\,\hbar c\,\alpha}$ — a bookkeeping consequence, not an input.

C.4 Spin-$\frac{1}{2}$: the quaternionic doublet

We reproduce GG-A2-GG6's construction (Arisaka, 2026, A2-GG6). The six-dimensional Minkowski space is realized as the space of 2×2 Hermitian *quaternionic* matrices,

$$\mathbb{R}^{1,5} \;\cong\; \mathrm{Herm}_2(\mathbb{H}) \;=\; \Big\{\, X = \begin{pmatrix} t+z & q \\ \bar{q} & t-z \end{pmatrix} : t, z \in \mathbb{R},\; q \in \mathbb{H} \Big\}, \tag{25}$$

on which the Lorentzian quadratic form is the reduced determinant

$$-\det X = -t^2 + z^2 + |q|^2, \qquad |q|^2 = q\bar{q} = q_0^2 + q_1^2 + q_2^2 + q_3^2, \tag{26}$$

of signature $(-,+,+,+,+,+)$ with total dimension $1+1+4 = 6$. The action $X \mapsto gXg^\dagger$ for $g \in \mathrm{SL}(2,\mathbb{H})$ preserves $\det X$, hence the metric; its kernel is $\{\pm\mathbf{1}\}$, exhibiting

$$\mathrm{Spin}(1,5) \;\cong\; \mathrm{SL}(2,\mathbb{H}) \tag{27}$$

as the double cover of the 6D Lorentz group — the quaternionic entry of the magic 2×2 sequence over the division algebras ($d = 3, 4, 6, 10$ for $\mathbb{R}, \mathbb{C}, \mathbb{H}, \mathbb{O}$; Hurwitz's 1898 classification underneath). Weyl spinors of the bulk are two-component *quaternionic* vectors — equivalently four-component complex vectors with a quaternionic structure — and their boundary projection carries an irreducible doublet. The half-integer label measured in 4D is the double-cover label of Eq. (27): forced by the dimension and the algebra, not selected from Wigner's menu (Wigner, 1939). This is the content of §12.3, with the dynamical reading (spin without spinning) in §28.

D Derivations for Q2: the landscape, the gates, and the absence of an exit

D.1 The family stratum and its Morse skeleton

The charged-lepton generations live on the family-projector stratum $\Sigma_{\text{fam}} = \mathbb{C}P^{N-1} = \mathbb{C}P^2$ (real dimension 4) (Arisaka, 2026, P2-N3; Arisaka, 2026, A9-SM). By GG-A6-GRIP's Morse-positivity theorem (T3.1, from CCI), the projected free-energy functional restricted to Σ_{fam} is a perfect Morse function (Morse, 1934) with exactly three non-degenerate critical points, of indices 0, 2, 4 (Lemma 4.2 of GG-P2-N3) — the minimal cell structure of $\mathbb{C}P^2$. The GRIP cascade chain orders them as

$$\underbrace{[\,\mathrm{ind}=4\,]}_{\text{depth }0} \xrightarrow{S_{[4]\to[2]}=2\pi} \underbrace{[\,\mathrm{ind}=2\,]}_{\text{depth }1} \xrightarrow{S_{[2]\to[0]}=\pi} \underbrace{[\,\mathrm{ind}=0\,]}_{\text{depth }2}, \tag{28}$$

with cumulative actions $0, 2\pi, 3\pi$ (Eq. 7 of the main text; **Figure 7**).

D.2 Basins, not saddles: the spectroscopy argument

One precision governs how Eq. (28) must be read (GG-P2-N3 §9.1; GG-A9-SM's cascade-depth section): the chain is the Morse *skeleton* of the stratum, while the physical generations are the index-0 minima of the depth-n *effective* landscapes hung on that skeleton — the index-4 and index-2 critical points are the GSSB *gates* the descent crosses, not the particles. All three generations are genuine Geometric Attractors, and this is not pedantry but spectroscopy: a saddle supports no sharply defined mass, whereas m_τ and m_μ are measured at the 10^{-4} relative level or better — precisely measurable masses are the experimental certificate that τ and μ are perfect GA's. What the higher generations are *not* is the ground state: only the depth-2 basin is the global minimum, the GGA.

D.3 The exit-gate calculus

Each non-ground basin possesses an exit gate with a Bogomolnyi toll: depth 0 exits through the index-4 gate at $S = 2\pi$; depth 1 through the index-2 gate at $S = \pi$ — Bogomolnyi-saturating actions (Bogomolny, 1976). In the GFF Morse framework the partial rate across a gate carries the instanton factor

$$\Gamma \;\propto\; e^{-S}, \tag{29}$$

combined with phase-space factors exactly as nuclear lifetime systematics combine barrier penetrability with phase space; the quantitative accounting for the τ–μ lifetime ratio (including why the $(m_\tau/m_\mu)^5$ phase-space factor dominates) is GG-P2-N3's §9.4 and is not duplicated here. The weak interaction is the physical implementer of every such crossing: within the boundary gauge group the $\mathrm{SU}(2)_L$ charged current is the only flavor-connecting channel, so every inter-basin descent observed in Nature is weak (Arisaka, 2026, A9-SM).

D.4 The no-exit-gate statement, assembled

Theorem 13.1 now assembles in four cited steps. *(i)* The depth-2 basin is the unique global minimum of the stratum (GFF-ST7; Appendix C.1). *(ii)* Its exit-channel set is empty: there is no critical point below it for a gate to lead to — "No exit gate exists; this is why the electron has never been observed to decay" (GG-P2-N3 §9.3, verbatim). *(iii)* Charge conservation, the premise of the textbook stability argument, is itself derived: the boundary $\mathrm{U}(1)_{\mathrm{EM}}$ descends from the bulk gauge factor (GG-A2-GG6, Theorem 3), so the standard lightest-charged argument survives *inside* the framework as a consistency check (§13.2). *(iv)* The forbiddance is structural, not statistical: even charge-violating channels (the Borexino search channel $e \to \nu\gamma$ (Borexino Collaboration, 2015)) require an exit from the basin, and there is none — which is why P1 covers them. The conditioning — GDOS internal; the Q3 import for "no lighter charged basin" — is declared in the main text and travels with this appendix.

E Derivations for Q3: the three legs of $N = 3$, digested

This appendix reproduces, at full derivational level, the three legs of GG-P2-N3's result (Arisaka, 2026, P2-N3), so that the student can check the count without opening the parent paper. The fences travel with the import: leg (L2) is conditional on the coupling clause and the integrality theorem L-INT (residue R-INT), exactly as in §16.

E.1 Leg L1: the CP lower bound $N \geq 3$

Theorem (MSMF lower bound; GG-P2-N3 Thm. 3.1). *Suppose the boundary observable spectrum admits a non-zero Jarlskog CP-violating invariant $J_{\text{CKM}} \neq 0$ in the quark sector. Then under MSMF, $N \geq 3$.*

Proof (reproduced). After Higgs descent the up- and down-type mass matrices are general complex $N \times N$ matrices, and the CKM matrix (Cabibbo, 1963; Kobayashi & Maskawa, 1973) $V_{\text{CKM}} = U_u^L U_d^{L\dagger}$ is an element of $U(N)$. Counting parameters: V_{CKM} has $N(N-1)/2$ mixing angles and $N(N+1)/2$ phases, of which $2N - 1$ are removable by independent rephasings of the up- and down-type flavor eigenstates; the physical CP-violating phase count is therefore

$$n_{\text{phase}}(N) = \frac{(N-1)(N-2)}{2}. \tag{30}$$

A Jarlskog invariant $J_{\text{CKM}} = \text{Im}\,(V_{ij} V_{kl} V_{il}^* V_{kj}^*)$ is non-zero iff at least one physical phase exists, i.e. $n_{\text{phase}} \geq 1$. Solving: $(N-1)(N-2)/2 \geq 1 \iff N \geq 3$ — at $N = 2$ the single complex phase is removable by rephasing; at $N = 1$ there is no mixing matrix at all. Empirically $J_{\text{CKM}} = (3.12^{+0.13}_{-0.12}) \times 10^{-5} \neq 0$ (Particle Data Group, 2024), and MSMF selects the smallest compatible N. Hence $N \geq 3$. □

The same argument runs in the leptonic sector with the PMNS matrix and is independently consistent with $N = 3$ (GG-P2-N3, with the global-fit sources cited there). Status: theorem, conditional on one empirical input (observed CP violation).

E.2 Leg L2: the budget upper bound $N \leq 3$

Lemma (cascade closure for $\mathbb{C}P^{N-1}$; GG-P2-N3 Lem. 4.x, reproduced). *The total instanton action accumulated along the chain $[2(N-1)] \to [2(N-2)] \to \cdots \to [0]$ is*

$$S_{\text{tot}}(N) = \pi \sum_{k=1}^{N-1} k = \pi\, \frac{N(N-1)}{2}. \tag{31}$$

Cascade closure requires $S_{\text{tot}}(N) \leq S_{\text{BI6}}^{\max}$.

Proof sketch (reproduced). The instanton action between adjacent critical points of indices $2k$ and $2(k-1)$ on $\mathbb{C}P^{N-1}$ with the Fubini–Study metric is, by direct integration of the Bogomolnyi-bound-saturating gradient flow, $S_{[2k]\to[2(k-1)]} = \pi k$ — the standard Morse–instanton computation (Helgason, 1979; Witten, 1982). Summing $k = 1, \ldots, N-1$ gives Eq. (31). □

The budget. The bound is closed by the capacity theorem **T-N3-6** of GG-P2-N3:

$$\mathrm{Cap}(N) = \pi \langle p_1(T\mathbb{C}P^{N-1}), [\mathbb{C}P^2] \rangle = \pi N, \qquad \mathrm{Cap}(3) = 3\pi, \tag{32}$$

derived there from the stratum's quantum geometry, conditional on the coupling clause and the integrality theorem L-INT, whose residue R-INT "is topological bookkeeping on a specific manifold, of the same kind as checking orientability, not a conceptual gap" (GG-P2-N3, verbatim; the N-independence demand of GG-A6-GRIP's open problem M10 is met by the same theorem, which consumes neither K nor J). Granted its premises,

$$\frac{N(N-1)}{2} \leq 3 \iff N \leq 3, \tag{33}$$

with exact saturation at $N = 3$: $S_{\mathrm{tot}}(3) = 3\pi$. The per-family formulation $S^{\max}_{\mathrm{BI6}}(N) = \pi N$ (the extensive form of T-N3-6; GG-P2-N3 Appendix C) gives the equivalent closure $N(N-1)/2 \leq N \iff N \leq 3$ and underlies the reachability reading: for $N \geq 4$ the descent's toll exceeds the stratum's capacity, and a fourth family's ground state would be *dynamically unreachable* — a reading that "inherits the conditioning of the capacity theorem and adds none of its own rigor" (GG-P2-N3 §9.6). The strict-positivity underpinning is dissolved upstream: the bulk-only derivation is closed in the negative (GG-P2-N3's rigidity lemma), the transport geometry is supplied at the Born theorem's own grade by its adiabatic theorems, and the residue is R-INT, of the integrality theorem L-INT — discharged on the benchmark background in GG-P2-N3's Appendix H. Status: theorem *conditional* on Eq. (32) with its stated premises (the coupling clause and L-INT/R-INT).

E.3 Leg L3: the codebook cross-check

The first-order ratio formulas of Appendix C.2 are functions of N once $J = 7$ and $L = 5$ are fixed by BI-6 closure:

$$\left.\frac{m_\tau}{m_\mu}\right|^{(1)} = \frac{NJ}{L}\, 2^{\,L-N}, \qquad \left.\frac{m_\mu}{m_e}\right|^{(1)} = \frac{L^4}{N}. \tag{34}$$

Evaluating: at $N = 2$ the formulas give 22.4 and 312.5 (off by 33% and 51%); at $N = 3$, 16.8 and 208.3 (within 10^{-3} and 8×10^{-3} of the measured 16.817 and 206.768); at $N = 4$, 11.2 and 156.25 (off by 33% and 24%) (Arisaka, 2026, P2-N3). The empirical ratios select $N = 3$ uniquely at the four-significant-figure level once the QD layer is applied (Appendix C.2). Status: consistency check — L3 validates, it does not independently force.

E.4 Closure

L1 gives $N \geq 3$ (conditional on observed CPV); L2 gives $N \leq 3$ (conditional on the coupling clause and L-INT); together $N = 3$ exactly, validated by L3's twelve four-significant-figure mass agreements. The electron's two excited copies, and only two, are thereby counted — and Q2 and Q3 interlock as the main text states: the same budget that stops the ladder guarantees the terminus is reachable and final.

F Derivations for Q4: the form-factor argument

This appendix expands the proof of Theorem 29.2: what is derived, from what, and exactly where Lemma 29.1 — and behind it AX-1 — enters. Per Remark 29.3, the form factor here is the falsification interface, not the ground: the appendix shows why the interface must read flat once the constitution has closed both the object and the registration. The constitutional Step 0 — AX-2's worldline coupling leaves no slot for a profile — is §26, presupposed throughout this appendix.

F.1 Setup

Operationally, elastic scattering off the electron at spacelike momentum transfer q measures the matrix element of the electromagnetic current, parameterized by form factors; "structure" means dependence of the *structural* form factor F on a length scale intrinsic to the electron, $F = F(q^2\ell_e^2)$ with $\ell_e \neq 0$. The Standard-Model radiative dressing (Schwinger's $a_e = \alpha/2\pi$ and its successors Schwinger, 1948, including the small hadronic and electroweak terms) is momentum-dependent but carries no new length: its scales are the probe's and the vacuum's, which is why precision $g-2$ constrains substructure only through a compositeness model (Dehmelt, 1988). The claim to be established is $F \equiv 1$: no ℓ_e exists.

F.2 Step 1: the electron supplies no length (theorem-level)

By Proposition 27.1, every structural datum of the electron is either (i) a dimensionless coordinate along I_r (the dyadic depth 2^J, the cascade level), (ii) a winding integer on S^1_θ, or (iii) a group label of the bulk spinor action. None is a function on $\mathcal{M}_4$; none defines a 4D length. The only dimensionful attribute the boundary sees is m_e — the GFF basin level — and a mass enters scattering kinematics (propagators, thresholds), not structure: the Compton wavelength $\hbar/m_e c$ is the scale of the *dynamics* of a point of mass m_e, present identically for a structureless Dirac particle, and its appearance in cross-sections is already part of the $F \equiv 1$ prediction, not a deviation from it.

A natural worry: the scale profile e^{-2r} of the canonical metric (GG-A2-GG6, Theorem 2) relates bulk position along I_r to 4D scale — is the electron's locus on I_r not, then, secretly a 4D length? It is a 4D *scale*, which is precisely not a 4D *extension*: the scale profile maps depth along I_r to the renormalization-group resolution at which boundary physics is read, uniformly for all processes, and not to a profile of the electron in the boundary coordinates. The distinction is the entire content of A2's statement that I_r is an RG direction, not a fifth spatial axis; a Kaluza–Klein theory makes the opposite choice, and the difference is observable, as §F.5 records.

F.3 Step 2: the readout supplies no length (Lemma RL, from AX-1)

What Step 1 cannot exclude is a length scale belonging to the *registration* itself: if the OGGEP bulk-to-boundary readout smeared every bulk configuration over some ℓ_{hol} in the boundary coordinates, all boundary particles would exhibit a universal form factor $F(q^2\ell_{\text{hol}}^2)$ regardless of their bulk structure.

The exclusion is constitutional. AX-1 (LC: Locality and Causality) of GG-A1-Constitution

(Arisaka, 2026, A1-Constitution) is not a statement about closed dynamics only. Its constitutional statement quantifies over "every admissible boundary intervention protocol" and requires that registered boundary records at time t depend only on boundary-accessible data in the causal past of t, with acausal effective kernels inadmissible. Its second constitutional clarification states that, because OGGEP defines observation as an open-system projection, LC "must hold for open evolution maps and measurement instruments, not only for closed unitary dynamics." Its third attaches admissible observables to *points* of the manifold (microcausality) and excludes fundamental extended objects — noting explicitly that the framework's two further dimensions are non-spatial. The registration channel is therefore not a loophole in AX-1's jurisdiction; it is among the named subjects of the axiom.

The derivation then has two branches, by where a scale-carrying kernel would put its support. *(a) Spacelike support* — registration at x drawing on configuration data at spacelike-separated points — contradicts the constitutional statement directly (the causal structure of Einstein, 1905, elevated to an axiom). *(b) Causal support* — retarded memory of depth ℓ_{hol}/c — is admissible under AX-1, but cannot produce the effect at issue: a kernel supported in the causal past of x has an equal-time slice consisting of the point x alone, so it generates frequency dispersion (the analyticity structure of causal response theory), not an equal-time spacelike profile — and the static structural form factor of §29 probes equal-time spacelike correlations only. We make the scope explicit, since the lemma's force depends on it: the claim concerns the *elastic, zero-energy-transfer* structure function — precisely the quantity whose deviation from unity would constitute substructure — while frequency-dependent response generated by causal memory belongs to the dressing layer of §29, carries the probe's and the vacuum's scales only, and is not structure. Hence no admissible readout supplies a spacelike scale: Lemma 29.1. The single step deserving further rigor is the static-limit factorization in branch (b) — that retarded channel memory contributes nothing to the elastic, zero-energy-transfer structure function in the OGGEP formalism. It is registered as open problem D-P3-1; we judge it formalization rather than missing physics, and state the judgment explicitly so that it, too, is auditable.

Remark: what AX-1 does and does not contribute. A critical reader will ask whether Q4 has now been answered by axiom — whether "pointlike because AX-1 says so" differs from the Standard Model's "pointlike by construction." It differs in the two places that carry this Part. First, an axiomatically pointlike field theory neither dissolves the self-energy crisis (the Standard Model's point electron still requires renormalization's subtraction) nor excludes that its pointlike field is the low-energy description of a composite — compositeness searches exist precisely because "by construction" is silent about deeper scales. Second, in GG-Theory the electron demonstrably *has* structure — the codebook integers of its mass, charge, and depth — so point-locality could not even be consistent if that structure were spatial. It is Proposition 27.1 (structure entirely along I_r, S^1_θ) that makes AX-1's point-locality *consistent*, and Lemma 29.1 that makes it *permanent* (no scale can hide in the readout). AX-1 contributes point-attachment; GG-A2-GG6's theorems contribute the consistency; the lemma contributes the permanence. The conjunction is the answer to Q4, and no single ingredient is.

Remark: universality, and the experimental texture of F5. If, contrary to Lemma 29.1, registration smearing existed, it would affect every boundary particle identically; an electron form-factor anomaly accompanied by identical anomalies in every other species, beyond their known internal structure, would point at the readout — that is, at a failure of the lemma's derivation — rather than at electron substructure. This is the experimental texture of kill criterion F5.

F.4 Step 3: scale-free normalized functions are constant

Granted Steps 1–2, F is a dimensionless function of q^2 alone with no scale available to nondimensionalize its argument; the only such functions are constants, and the normalization $F(0) = 1$ — the probe at zero momentum sees the whole quantized charge, §12.2 — fixes the constant. Hence $F \equiv 1$, all moments vanish, and no substructure exists at any scale. The logical structure mirrors the classic scale-argument for the inverse-square law; its strength is entirely inherited from the two scale-exclusion steps, which is why the fence sits at Step 2 and nowhere else.

F.5 Contrast: extra dimensions that are spatial (Kaluza–Klein)

The argument fails instructively for an electron with structure along extra dimensions that are genuinely *spatial* — the Kaluza–Klein construction, in which the extra circle is a small circle *in space* of radius R. There R *is* a length, boundary physics sees a Kaluza–Klein tower at $\hbar/R$, and form factors deviate as q^2R^2 — structure at a scale, the compositeness signature. The empirical absence of any such tower for the electron is thus not merely consistent with the GG-Theory bulk; it is what the non-spatiality of I_r, S^1_θ predicts, and the contrast is the cleanest observable distinction between "two more dimensions of space" and "a scale direction and a phase direction."

G Derivations for Q5: the parallel chains, the unified equation, and the open-system arrows

This appendix reproduces, in digest and with citation, the content of GG-A5-GDOS's Part VI — "Unification of General Relativity and QED" (Arisaka, 2026, A5-GDOS) — which is the constitutional foundation of Q5's answer (and, through the worldline coupling, of Q4's: see §26). The parent treatment is written so that "a reader meeting gauge theory for the first time can follow every line"; we compress it to the load-bearing steps and refer the student to GG-A5-GDOS for every omitted manipulation.

G.1 Chain (A): GG-6 → 5D GR → 4D GR → Newton → $F = ma$

The gravitational chain descends the two non-spatial dimensions one at a time, reducing a single geometric object — the bulk metric — with no force postulated anywhere. Start from the six-dimensional Einstein–Hilbert action on the canonical bulk,

$$S_6 = \frac{M_6^4}{2}\int d^6x\,\sqrt{-g_6}\,R_6, \qquad ds_6^2 = e^{-2r}g_{\mu\nu}(x)\,dx^\mu dx^\nu + dr^2 + d\theta^2. \tag{35}$$

Step A1 (6D → 5D): nothing depends on the phase θ and the circle is flat, so the θ-integral contributes the circumference, $M_5^3 = 2\pi M_6^4$ — reducing on a gauge phase costs nothing geometrically. *Step A2 (5D → 4D):* the determinant scales as $\sqrt{-g_5} = e^{-4r}\sqrt{-g_4}$ and the four-dimensional curvature as $R_5 \supset e^{+2r} R_4$, so the scale-profile factors combine to e^{-2r} and the radial integral is elementary:

$$M_{\rm Pl}^2 = M_5^3 \int_0^K e^{-2r}\, dr = \pi\, M_6^4\, (1 - e^{-2K}), \tag{36}$$

the scale-profile-weighted overlap integral that sets Newton's constant $G_N = 1/(8\pi M_{\rm Pl}^2)$. *Step A3:* varying the resulting 4D Einstein–Hilbert action gives Einstein's field equation; the weak-field, static limit gives the Poisson equation $\nabla^2\Phi_{\rm N} = 4\pi G_N \rho$ and hence Newton's potential $\Phi_{\rm N} = -G_N M/r$. *Step A4:* the geodesic equation of the 4D metric, in the same limit, is $F = ma$ with $\vec{F} = -m\nabla\Phi_{\rm N}$. Gravitation is, throughout, the statement that matter follows the geodesics of the reduced metric.

G.2 Chain (B): GG-6 → 4D QED → Maxwell + Lorentz → Coulomb

The electromagnetic chain runs exactly parallel; the geometric object is now the bulk gauge connection whose holonomy lives on S^1_θ, and the electric charge is the integer-quantized momentum of that holonomy. *Step B1:* a charged field's unobservable local phase requires a connection A_μ for its covariant derivative (Weyl, 1929) (the non-Abelian generalization being Yang & Mills, 1954); the curvature of that connection is the field strength $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$, and the bulk gauge action reduces (by the same 2π and scale-profile integrals as Chain A) to the 4D Maxwell action. *Step B2:* varying it gives Maxwell's equations. *Step B3:* the minimally-coupled worldline

$$\mathcal{L} = \tfrac{1}{2}\, m\, g_{\mu\nu}\dot{x}^\mu \dot{x}^\nu + q\, A_\mu \dot{x}^\mu \tag{37}$$

— the complete matter coupling permitted by AX-2 (§26) — yields, on variation, the Lorentz force. *Step B4:* the static limit of Maxwell's equations is again a 3D Poisson equation, $\nabla^2\phi = -\rho_e/\varepsilon_0$, whose Green's function $-1/(4\pi r)$ gives Coulomb's law, attraction and repulsion arriving as the two signs of q. The two chains converge on the unified equation of motion,

$$m(\ddot{x}^\mu + \Gamma^\mu_{\nu\lambda}\dot{x}^\nu \dot{x}^\lambda) = q\, F^\mu{}_\nu\, \dot{x}^\nu \qquad \text{(Eq. 12)}, \tag{38}$$

one trajectory governed by two curvatures of one composite connection.

G.3 The gravity–electricity dictionary

Table 10 reproduces, in digest, the term-by-term dictionary of GG-A5-GDOS's Part VI. The student should read it column against column: the parallelism is exact in mathematical form, and the three physical differences (universal vs quantized charge; bulk-set vs boundary-running coupling; $\mathrm{Spin}(1,5)$ vs $\mathrm{U}(1)_{\rm em}$) are themselves derived, not modeled.

Table 10: The gravity–electricity dictionary, digested from GG-A5-GDOS's Part VI (Arisaka, 2026, A5-GDOS): one bulk, two curvatures, term by term. Read across a row and the same geometric object appears twice, once as gravitation and once as electromagnetism; read down a column and each chain stands complete on its own. The reason for setting them side by side is that neither column contains a term the other lacks.

Aspect	**Gravitation (Chain A)**	**Electromagnetism (Chain B)**
Non-spatial dimension	5th: scale interval I_r (scale profile)	6th: phase circle S^1_θ (holonomy)
Geometric object	scale-profile metric block $e^{-2r}g_{\mu\nu}$	gauge connection on S^1_θ (Wilson line)
Connection	Christoffel $\Gamma^\mu_{\nu\lambda}$	gauge potential A_μ
Curvature	Riemann $R^\mu{}_{\nu\lambda\sigma}$	field strength $F_{\mu\nu}$
Test-particle charge	mass–energy m (universal)	electric charge $q = ne$ (holonomy momentum)
Charge quantization	none (m continuous)	$q = ne$ from compact S^1_θ
Massless mediator	graviton $h_{\mu\nu}$	photon A_μ
Coupling constant	$G_N = 1/(8\pi M_{\rm Pl}^2)$ (bulk)	α (boundary running; App. C.3)
Static field equation	$\nabla^2\Phi_{\rm N} = 4\pi G_N\rho$	$\nabla^2\phi = -\rho_e/\varepsilon_0$
3D Green's function	$-1/(4\pi r)$	$-1/(4\pi r)$
Conserved current (Ward)	$T_{\mu\nu}$ (translations)	J^μ ($\mathrm{U}(1)_{\rm em}$)
Equation of motion	$m(\ddot{x} + \Gamma\dot{x}\dot{x}) = 0$	$m(\ddot{x} + \Gamma\dot{x}\dot{x}) = qF\dot{x}$

G.4 Why the two laws are twins: the three ingredients

Both forces are boundary exports of massless sectors of the same composite connection $\mathcal{A}_{\rm tot} = \omega \oplus A$, and the parallelism rests on exactly three shared ingredients (GG-A5-GDOS, Part VI): *(i)* a massless mediator in the infrared, protected on each side by an unbroken symmetry (4D diffeomorphism invariance; unbroken $\mathrm{U}(1)_{\rm em}$); *(ii)* Gauss-law flux conservation in three spatial dimensions — the static limits of both field equations are 3D Poisson equations sharing the Green's function $-1/(4\pi r)$, which is where the inverse square comes from on both sides at once; *(iii)* a conserved four-current defined by a Ward identity — Noether's theorem (Noether, 1918) in its quantum form — inherited from the bulk through the boundary reduction and non-anomalous by BI-6 ($T_{\mu\nu}$ from boundary translations; J^μ from boundary gauge invariance). The electron-side significance is the answer to Q5 given in §33.2: with both laws derived as curvatures of one geometry, "responding to a field" is generalized free fall, and the old picture of a force *transmitted to* the electron is retired the way "the pull on the apple" was retired in 1915.

G.5 The open-system layer: which sector descends

The geodesic statement of this appendix is conservative; the GDOS layer supplies arrows, and the two non-spatial dimensions assign them without ambiguity. The GFF monotonicity law $d\mathcal{F}_{\mathsf{GFF}}/dt \le 0$ (GG-A6-GRIP, GFF-ST6) and the GRIP-In regime (def:GRIPin) are *scale-sector* statements: their landscape is the family stratum of Appendix D, their descent is the gate calculus of Appendix D.3, and their action is local — a transmutation of the occupant, with no spatial transport. Nothing in Chains (A) or (B) descends: the unified equation (38) is time-reversal even, and an electron bending in a static field loses nothing. The dissipative channel of *motion* is radiation — Larmor's loss, the reaction force of Dirac (1938) — which removes orbital energy through the open boundary; its GDOS reading (the open boundary doing to motion what GRIP-In does to identity) is this paper's interpretive Reading 34.1, corrected from an earlier tilted-landscape formulation that mis-assigned the sector (§34 records the withdrawal). The boundary kinematics remain Newton–Lorentz plus radiation reaction, exactly as the derived equations say they should; **Figure 11** draws the two sectors. The quantitative parent of this assignment is the radiative completion of GG-A5-GDOS's Part VI (Arisaka, 2026, A5-GDOS): synchrotron damping and gravitational-wave inspiral worked side by side as the gradient sector of the canonical GDOS current, with the conservative orbit as circulation, and the quantitative closure derived from the field trace (drift = retarded flux; closed-form mobility; Larmor and Peters coefficients exact; universal C_q) — GG-A5-GDOS Open Problem O7 is thereby Resolved — the covariant kernel itself is derived there in closed form (causal, passive, Landau–Lifshitz-exact to $(\hbar\omega/M_{\mathrm{lock}}c^2)^2$ at laboratory frequencies), with the classical runaway obstruction dissolved by the Q4 mass doctrine of Part VI (§34 imports the example and the status together).

G.6 What a student should now be able to do

The reader who has worked through Appendices C–G can: reproduce all six first-order charged-lepton numbers and both exact ratios from the five ledger integers; apply the QD rationals and verify the printed masses to all digits; count CP phases for general N and rederive $N \geq 3$; sum the gate tolls and rederive $N \leq 3$ given the budget (saying exactly where the conjecture enters); assemble the no-exit-gate argument in four cited steps; run both reduction chains — the 2π integral, the scale-profile integral Eq. (36), the minimal coupling, the Green's function — and arrive at Newton, Coulomb, and the unified equation of motion from one bulk action; recite the dictionary; and state which of the six answers are theorems, which are codebook results, which are imports, and which are readings — which is to say: audit this paper. That, and not assent, is what these appendices are for.

H Empirical anchors

All values verified against current sources on June 11, 2026; the table is the paper's single point of empirical reference, and Part VIII consumes it.

Table 11: Empirical anchor table, with verification date and sources. Every empirical number this paper leans on, the experiment that supplies it, and the date the value was checked. The anchors are listed apart from the predictions they bound so that the inputs can be re-verified without re-reading the argument, and so that a value which moves has one place to be found and corrected.

Anchor	**Value**	**Source**
Electron lifetime	$\tau_e > 6.6 \times 10^{28}$ yr (90% C.L.)	Borexino (Borexino Collaboration, 2015); still the world's best bound
Electron $g/2$	1.001 159 652 180 559(13) (0.13 ppt)	Fan et al. (2023)
α^{-1} (CODATA 2022)	137.035 999 177(21)	(CODATA, 2022)
α^{-1} (Rb, 2020)	137.035 999 206(11)	Morel et al. (2020); $> 5\sigma$ from Cs
α^{-1} (Cs, 2018)	137.035 999 046(27)	Parker et al. (2018)
$m_e c^2$	0.510 998 950 69(16) MeV	CODATA 2022 (CODATA, 2022); cf. PDG (Particle Data Group, 2024)
Compositeness reach	contact-interaction scales excluded to $\mathcal{O}(10)$ TeV (model-dependent)	(ALEPH et al., 2006; Eichten, Lane & Peskin, 1983) and PDG listings (Particle Data Group, 2024)
Light-neutrino count	$N_\nu = 3$ (2.9963 ± 0.0074)	LEP (ALEPH et al., 2006)
GG-Theory comparators	$m_e^{\mathrm{QD}} = 0.511097845$ MeV (residual 1.9×10^{-4}); α^{-1}: $2^J + N^2 = 137.0$, QD-completed	(Arisaka, 2026, A9-SM); declared in §12.1, §12.2

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.

References

The reference list is organized in two sections, in line with the GG-Theory house style. **Section A** lists the fourteen sister papers of the GG-Theory cohort cited in this paper, in the canonical order of the program; **Section B** lists the external literature, alphabetically by first author. Every entry carries a **Relevance** paragraph stating what the work contributes to this paper and where it enters, followed by 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 charter: the four axioms (including MSMF, "Maximum Symmetry, Minimum Freedom") and seven postulates underlying every framework element consumed in Part II; its axiom AX-1 (LC: Locality and Causality) — formulated by constitutional clarification for open evolution maps and measurement instruments, with microcausality attaching observables to points — is the source from which Lemma 29.1 is derived (§29; Appendix F, Step 2). First cited in §6.1.

Arisaka, K. (2026). GG-Theory with GG-6: Geometry–Gauge Locking at the 6D Bulk (GG-6) at the Heart of Grand Geometric Theory (GG-Theory). Arisaka-GG-A2-GG6.
Preprint, available at https://preprints.arisaka-gg.org/a2-gg6/.
Relevance. The bulk paper and largest theorem source of Part VI: Theorem 1 (the non-spatial directions I_r, S^1_θ), Theorem 2 (parameter-free canonical metric), the magic-square proposition ($\mathrm{Spin}(1,5) \cong \mathrm{SL}(2,\mathbb{H})$) behind spin-$\frac{1}{2}$, and Theorem 6 (Diophantine uniqueness of the OGN-5 ledger). First cited in the Executive Summary.

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 anomaly paper: BI-6 closure and the integer-ledger constraints consumed via the GG-P2-N3 import (Part IV). The budget value 3π is *quoted*, not derived, in its ledger; the value itself is the capacity theorem T-N3-6 of GG-P2-N3, whose conditioning (the coupling clause and L-INT) this paper inherits. First cited in §6.1.

Arisaka, K. (2026). From Euclid to GG-6: The Realization of Euclid's Elements in Six Dimensions — GU-5, OGN-5, and a Parameter-Free Reconstruction of Modern Physics. Arisaka-GG-A4-Euclid.
Preprint, available at https://preprints.arisaka-gg.org/a4-euclid/.

Relevance. Source of T-Euclid-4 (the elementary charge derived, not primitive) and the GU-5 constant-absorption lineage by which dimensionful 4D mysteries become bookkeeping along the scale direction — consumed in §12.2 and Part VI. First cited in §8.

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 framework within which the ground-state theorems of Part III hold. Its open problem O3 records strict GFF Morse-positivity as unsettled; that fence is restated wherever this paper's theorems lean on the landscape machinery, and the sensing reading of Part VII is grounded in — but not asserted by — this paper. Its Part-VI radiative completion carries the synchrotron and binary-inspiral worked examples that §34 imports in digest, together with the field-trace closure (Larmor and Peters coefficients exact) and the covariant kernel in closed form — its Open Problem O7 now Resolved, with the no-runaway theorem leaning on this paper's Q4 mass doctrine. First cited in §8.

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. Source of the GFF landscape and its structure theorem GFF-ST7 (unique deepest attractor), the regime definitions def:GRIPin and def:GRIPout, and the definition def:GGA on which Theorems 11.1 and 13.1 stand; its cascade-closure theorem T4.1 consumes the budget value whose missing derivation is its open problem M10. First cited in §8.

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. Source of the universal-identity theorem (T-A8.9 = T-QM-9) consumed in Theorem 11.1, and of the bulk-to-boundary projection framework within which Lemma 29.1 operates; the remaining formalization step of the lemma's static limit (D-P3-1) is to be carried out in its open-channel formalism. First cited in §11.1.

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 single largest upstream source: the charged-lepton codebook (y_e, QD completion, $\mathcal{R}_e = 641/640$), the dyadic-closure α theorem, the geometric-origin-of-identity section, the inverse-square forces section, the weak-as-GRIP-In doctrine, and the lepton cascade-depth assignment (e = depth-2 GGA) — consumed throughout Parts III, IV and VII at the locations registered in Appendix B. First cited in §8.

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-boundary closure of the program; cited for cohort context in Part II — the same ledger that fixes the electron's numbers fixes the cosmic inventory, which is the breadth claim behind "ground state of nature." First cited in §8.

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: proves the regime theorem T-GGA-as-Ground-State (the cascade output at each layer is the ground state, not merely a stable basin) whose deployment on the charged-lepton stratum is Theorem 11.1; the regime definitions remain at runtime level in GG-A6-GRIP, per the division of labor recorded in §11.2. First cited in §8.

Arisaka, K. (2026). Why Three Generations: A Three-Leg Derivation of $N_g = 3$ from BI-6, MSMF, and GDOS Morse Stability. Arisaka-GG-P2-N3.
Preprint, available at https://preprints.arisaka-gg.org/p2-n3/.
Relevance. The sister paper: owns Q3 (the ladder, $N = 3$, and the comparisons with prior approaches), the basins/gates ontology and no-exit-gate statement deployed in Theorem 13.1, the reachability reading, and the coupling-clause + L-INT fences that travel verbatim with every Q3 import in Part IV. First cited in §3.

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 origin-of-i member paper of the Foundations Branch: derives the boundary's imaginary unit — the i on which the electron's quantum mechanics runs — from two real sources, the compact phase circle and the causal clock, whose forced agreement on the charged sectors is the shared complex structure that the electron, as the lightest charged state, carries. Cited at roster level in §6.1. 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. The CPT member paper of the Foundations Branch: C, P, and T as orientation reversals of the three real bulk factors, and the circle–clock handshake whose first receipt is the electron's twin — the positron. Cited at roster level in §6.1. First cited in §6.1.

Arisaka, K. (2026). The Qi-4 Pillars — Qi-QUA, Qi-EP, Qi-CON, Qi-HAL: The Quantum-Information Backbone of GDOS. Arisaka-GG-A7-Qi4.
Preprint, available at https://preprints.arisaka-gg.org/a7-qi4/.
Relevance. The quantum-information half of the pair whose geometric half this paper leans on throughout. GG-A7-Qi4 supplies the runtime vocabulary in which GRIP-In and GRIP-Out are defined, and the electron's readout — one basin, read once — is stated in that vocabulary rather

than in a private one. Cited for the vocabulary and for the information charge that partners the baryonic one; no numerical result of this paper depends on it.

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 first of the two phenomenology papers on the astrophysical side of the same geometry. It carries no result this paper uses, and the honest description of the relation is that the two are siblings rather than neighbors: the corridor C2 reads along the scale direction is the same direction along which this paper places the electron's structure. Cited at roster level in the cohort map, and named as roster level here.

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 second phenomenology paper, and the other end of the same open-system reading. Where this paper asks what a projection does to a single particle, C3 asks what it does to a horizon, and both answers are statements about the same boundary law. Nothing in the electron argument turns on the horizon result. Cited at roster level in the cohort map, and the note says so.

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 paper of the Particle Branch, and this paper's sibling in method rather than in subject. Both take the two non-spatial directions literally and both cash that into something a measurement can refuse: P1 into a resonance at a stated mass, this paper into a form factor that must stay flat. The lock cluster says nothing about the electron and the electron says nothing about the lock cluster; what they share is the geometry that produces both, and the willingness to name what would retire it.

Arisaka, K. (2026). The Proton as the Ground Geometric Attractor of Matter: The Eleven Questions of the Proton, Closed and Fenced within GG-Theory. Arisaka-GG-P6-Proton.
Preprint, available at https://preprints.arisaka-gg.org/p6-proton/.
Relevance. The closest relative of this paper in the whole cohort, and the one worth reading beside it. P6 argues that the proton never decays because baryon number is gauged and its anomaly is canceled; this paper argues that the electron never decays because there is no gate out of the deepest basin. Two particles, two absolute stability claims, one integer ledger underneath both — and two standing falsifiers that would be lost together. Cited in Part III where the electron's own absolute stability is stated.

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 background this paper's central negative claim needs and does not itself supply. The result in Part III is an *absence* — no exit gate — and an absence reads as a result only to someone who already accepts that a conservation statement need not descend from a symmetry. W1 is the cohort's survey of exactly that century-long shift. It supplies no number and no theorem this paper uses. Cited at roster level in the cohort map.

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 classification the mechanism of Part VII belongs to. The charge quantization argued there is a winding number on a compact phase direction, which is protection by holonomy rather than by symmetry, and that is W2's subject. Cited in Part VII where the winding argument is made, and at roster level in the cohort map — the second because the roster owes it, the first because the mechanism is W2's.

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 first deployment of the GGA vocabulary on a companion stratum (the Kaxion as the deepest stable valley of its landscape); cited in Part II as precedent — the electron and the dark sector are ground states of the same constitutional principle. First cited in §8.

B. Other references

Abbott, B. P., et al. (LIGO Scientific Collaboration and Virgo Collaboration). Observation of gravitational waves from a binary black hole merger. *Physical Review Letters* **116** (2016) 061102.
Relevance. The first direct detection of gravitational waves: the final inspiral, merger, and ringdown of a binary black hole, recorded as the chirp the quadrupole formula predicts. Cited in §34 as the direct observation of the metric-sector twin of synchrotron damping — the gradient-sector descent of GG-A5-GDOS's radiative completion, watched in real time. First cited in §34.

Abraham, M. Prinzipien der Dynamik des Elektrons. *Annalen der Physik* **315** (1903) 105–179.
Relevance. The first dynamical model of an extended electron, opening the classical self-energy crisis that Part VI engages and dissolves. First cited in §25.

ALEPH, DELPHI, L3, OPAL Collaborations & LEP Electroweak Working Group. Precision electroweak measurements on the Z resonance. *Physics Reports* **427** (2006) 257–454.
Relevance. The empirical bound on the number of light neutrino species, $N_\nu = 2.9963 \pm 0.0074$: one of the declared empirical inputs that travels with the Q3 import (Part IV) and the anchor of P4; also the source of LEP contact-interaction reach quoted in Appendix H. First cited in §16.

Anderson, C. D. The positive electron. *Physical Review* **43** (1933) 491–494.
Relevance. The discovery of the positron — Dirac's "hole" photographed in a cloud chamber within a year of the prediction — and, for this paper, the protagonist of the sixth question. Part V asks what the particle in Anderson's photograph *is*, and answers: the electron's one basin, read in the conjugate orientation — with the origin of the twin imported at theorem grade and the same-basin reading priced (Table 3, D-P3-4). A student should still read Anderson for the experimental humility of the prose: the most consequential discovery of 1930s physics is reported in four pages of careful track analysis. First cited in §2.

Aoyama, T., Hayakawa, M., Kinoshita, T. & Nio, M. Tenth-order QED contribution to the electron $g-2$ and an improved value of the fine structure constant. *Physical Review Letters* **109** (2012) 111807.
Relevance. The summit of perturbative QED: 12,672 tenth-order diagrams, computed over decades, matching experiment through twelve digits. It is the precision partner of Fan et al. (2023) in prediction P3 (§39) and the sharpest existing statement that the electron's moment is dressing, not structure. For the student it is also a methodological landmark: what "the Standard-Model prediction for a point fermion" means, made concrete to five loops. First cited in §39.

Bogomolny, E. B. Stability of classical solutions. *Soviet Journal of Nuclear Physics* **24** (1976) 449–454.
Relevance. Source of the Bogomolnyi bound: the energy of a topological configuration is bounded below by its topological charge, with equality on first-order (self-dual) solutions. The gate tolls $S = \pi k$ of the lepton cascade (Eq. 7; Appendix D.3) are Bogomolnyi-saturating instanton actions, which is why they are exact integers times π rather than landscape-dependent numbers — the structural reason the budget arithmetic of Appendix E.2 can be arithmetic at all. First cited in §D.3.

Agostini, M., et al. (Borexino Collaboration). Test of electric charge conservation with Borexino. *Physical Review Letters* **115** (2015) 231802.
Relevance. The world's best lower bound on the electron lifetime, $\tau_e > 6.6 \times 10^{28}$ yr (90% C.L.), via the charge-violating channel $e \to \nu\gamma$: the empirical anchor of Q2 and of prediction P1 / kill criterion F1. First cited in §13.1.

Born, M. Zur Quantenmechanik der Stoßvorgänge. *Zeitschrift für Physik* **37** (1926) 863–867.
Relevance. The probability rule of quantum mechanics, postulated in a footnote in 1926 and never derived within the formalism it completes. Cited in §45: its derivation as a theorem of the boundary reduction (Arisaka, 2026, A8-QM) is the centenary's other bookend — the dice of the boundary obtained from the determinism of the bulk. First cited in §45.

Brodsky, S. J. & Drell, S. D. Anomalous magnetic moment and limits on fermion substructure. *Physical Review D* **22** (1980) 2236–2243.
Relevance. The classic analysis converting $g-2$ precision into substructure bounds: a composite electron of size R generically shifts a_e by $\mathcal{O}(m_e R)$, so the measured agreement with QED pushes R far below scattering reach. This is the engine behind Dehmelt's famous radius bound

(Dehmelt, 1988) and the reason §25 calls such bounds model-dependent: the conversion requires a compositeness ansatz, exactly the assumption Theorem 29.2 renders permanently idle. First cited in §25.

Cabibbo, N. Unitary symmetry and leptonic decays. *Physical Review Letters* **10** (1963) 531–533.
Relevance. The two-family mixing angle — the seed of the CKM matrix. Cabibbo's single parameter became, at three families, the four-parameter matrix whose single physical phase carries CP violation; the counting that turns this structure into the lower bound $N \geq 3$ is reproduced in Appendix E.1. For the student: this is what it looks like when one rotation angle, honestly bookkept, reorganizes the weak interactions of every quark. First cited in §E.1.

Candelas, P., Horowitz, G. T., Strominger, A. & Witten, E. Vacuum configurations for superstrings. *Nuclear Physics B* **258** (1985) 46–74.
Relevance. The seminal Calabi–Yau compactification: the canonical construction in which the extra dimensions are *spatial* and carry continuous moduli — the structural contrast drawn in §38.2. First cited in §38.2.

Carter, B. Global structure of the Kerr family of gravitational fields. *Physical Review* **174** (1968) 1559–1571.
Relevance. Source of the remarkable observation that a Kerr–Newman source with the electron's parameters has gyromagnetic ratio $g = 2$ — the geometric-electron tradition engaged in §37. First cited in §37.

Christenson, J. H., Cronin, J. W., Fitch, V. L. & Turlay, R. Evidence for the 2π decay of the K_2^0 meson. *Physical Review Letters* **13** (1964) 138–140.
Relevance. The discovery of CP violation — the single empirical input on which leg (L1) of the $N = 3$ derivation stands (§16; Appendix E.1). A fifty-seven-event excess in a beamline experiment, and its consequence, half a century later, is a lower bound on the number of families of matter: few papers teach more vividly that the count of fundamental inputs to a framework can hinge on one decisive measurement. First cited in §16.

Mohr, P. J., Newell, D. B., Taylor, B. N. & Tiesinga, E. CODATA recommended values of the fundamental physical constants: 2022. arXiv:2409.03787 (2024).
Relevance. Source of the precision anchors $m_e c^2 = 0.51099895069(16)$ MeV and $\alpha^{-1} = 137.035999177(21)$ against which the QD-completed codebook values are registered, with the 1.9×10^{-4} mass residual declared in §12.1. First cited in §12.1.

Compton, A. H. A quantum theory of the scattering of X-rays by light elements. *Physical Review* **21** (1923) 483–502.
Relevance. The electron as point target: X-ray scattering with the kinematics of a billiard-ball collision, establishing that radiation exchanges momentum with single electrons. Compton scattering is the ancestor of every probe in the form-factor story of §29 — the first experiment to ask, in effect, "what does the electron look like at short wavelength?" and to receive the answer this paper promotes to law: a point. First cited in §2.

Davisson, C. & Germer, L. H. Diffraction of electrons by a crystal of nickel. *Physical Review* **30** (1927) 705–740.

Relevance. The electron as wave: de Broglie's hypothesis confirmed in nickel diffraction. Together with de Broglie (1925) it fixes the dual character that any account of the electron must carry — and it sharpens Q4: the object that diffracts like a wave nevertheless scatters, at every accessible q^2, like a structureless point (§2). The tension is resolved in this paper by relocating structure off the spatial directions entirely. First cited in §2.

de Broglie, L. Recherches sur la théorie des quanta. *Annales de Physique* (Paris) **3** (1925) 22–128.

Relevance. The matter wave: the doctoral thesis that assigned the electron a wavelength and thereby founded wave mechanics. Cited in §2 as part of the electron's foundational résumé — the same particle whose wave nature built quantum mechanics is the particle whose five elementary properties remained unexplained for the century that followed; this paper's preface is addressed to exactly that irony. First cited in §2.

Dehmelt, H. A single atomic particle forever floating at rest in free space: new value for electron radius. *Physica Scripta* **T22** (1988) 102–110.

Relevance. The classic $g-2$ argument bounding an electron "intrinsic radius" far below scattering reach — model-dependent, as stated there and in §29; engaged as the empirical-anchor tradition that P2/F2 sharpens into a scale-free prediction. First cited in §25.

Dirac, P. A. M. The quantum theory of the electron. *Proceedings of the Royal Society of London A* **117** (1928) 610–624.

Relevance. The relativistic wave equation: spin-$\frac{1}{2}$ and $g = 2$ emerging unbidden from the marriage of quantum mechanics and special relativity, with the positron implicit in the negative-energy sea. For this paper Dirac 1928 is the standard of what "explaining a property of the electron" should mean — a property falling out of a structural requirement rather than being fitted — and §12.3 (with Appendix C.4) is the attempt to meet that standard one level deeper: why the world's spinor algebra is quaternionic in the first place. First cited in §2.

Dirac, P. A. M. Quantised singularities in the electromagnetic field. *Proceedings of the Royal Society A* **133** (1931) 60–72.

Relevance. The founding document of the sixth question: the concession, three years after the equation, that the negative-energy shadow is "a new kind of particle, unknown to experimental physics, having the same mass and opposite charge to an electron." Part V reads the episode as the century's most successful mis-filing: a consistency demand mistaken for an explanation. First cited in §2.

Dirac, P. A. M. Classical theory of radiating electrons. *Proceedings of the Royal Society of London A* **167** (1938) 148–169.

Relevance. The definitive classical point-electron dynamics (Lorentz–Dirac equation), whose runaway and pre-acceleration pathologies close the classical chapter of Q4's crisis engaged in §25. First cited in §25.

Dyson, F. J. The radiation theories of Tomonaga, Schwinger, and Feynman. *Physical Review* **75** (1949) 486–502.

Relevance. The unification of the three renormalization schemes into one machine, completing the demonstration that QED's infinities can be consistently absorbed. In the historical ledger of §25 this is the moment the self-energy crisis was *sidestepped* with full rigor — the subtraction became a theory — and the moment "why is the electron pointlike?" stopped being asked because the question's penalty had been administratively removed. Required reading for understanding what renormalization does and does not explain. First cited in §25.

Eichten, E., Lane, K. & Peskin, M. New tests for quark and lepton substructure. *Physical Review Letters* **50** (1983) 811–814.

Relevance. The contact-interaction formalism by which compositeness scales are bounded; the framework of the experimental reach quoted in Appendix H, and the standard-physics counterpoint to Theorem 29.2's scale-free prediction. First cited in §25.

Einstein, A. Zur Elektrodynamik bewegter Körper. *Annalen der Physik* **17** (1905) 891–921.

Relevance. Special relativity: the causal structure — no influence outside the light cone — that AX-1 elevates from property to constitutional axiom. Lemma 29.1's branch (a) (Appendix F, Step 2) is, at bottom, Einstein's prohibition applied to the registration channel itself; the student tracing the pointlikeness theorem to its roots ends here, in the paper that made simultaneity local. First cited in §F.3.

Einstein, A. Die Feldgleichungen der Gravitation. *Sitzungsberichte der Preussischen Akademie der Wissenschaften* (1915) 844–847.

Relevance. The field equations of general relativity — the original demonstration that a force can be abolished into geometry. Chain (A) of §33.1 (Appendix G.1) descends exactly these equations from the 6D bulk, and the entire Q5 answer of this paper is Einstein's move performed a second time, on the gauge sector: what 1915 did to "the pull on the apple," the composite connection does to "the force on the electron." First cited in §33.1.

Fan, X., Myers, T. G., Sukra, B. A. D. & Gabrielse, G. Measurement of the electron magnetic moment. *Physical Review Letters* **130** (2023) 071801.

Relevance. The most precise property measurement of any elementary particle ($g/2$ to 0.13 ppt): the empirical anchor of structurelessness (P3) and of the QED-dressing reading of a_e in §29. First cited in §25.

Fee, M. S., Chu, S., Mills, A. P., Chichester, R. J., Zuckerman, D. M., Shaw, E. D. & Danzmann, K. Measurement of the positronium $1\,^3S_1$–$2\,^3S_1$ interval by continuous-wave two-photon excitation. *Physical Review A* **48** (1993) 192–219.

Relevance. Positronium spectroscopy as a mass-equality balance: the source of the $|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$ bound (90% C.L.) quoted in the falsifier face of §23 — for this paper, a bound on how differently the one basin can read in its two orientations. First cited in §23.

Feinberg, G. & Goldhaber, M. Microscopic tests of symmetry principles. *Proceedings of the National Academy of Sciences* **45** (1959) 1301–1312.

Relevance. The founding charter of the conservation-law test program: if a symmetry is exact, prove it by lifetime, and if not, find the decay. The electron-lifetime searches culminating in Borexino Collaboration (2015) descend from this paper's logic, and prediction P1 (§39) is its GG-Theory endpoint: the search must continue forever and must find nothing, forever. First cited in §13.1.

Fermi, E. Versuch einer Theorie der β-Strahlen. *Zeitschrift für Physik* **88** (1934) 161–177.
Relevance. The first theory of the weak interaction — the four-fermion contact form that grew into the electroweak gauge sector. In this paper's ontology the weak interaction is Nature's implementer of GRIP-In on the matter strata (§15): every arrow in the $\tau \to \mu \to e$ descent is a Fermi transition, which makes this the paper in which the road between the basins was first paved. First cited in §15.

Feynman, R. P. Space-time approach to quantum electrodynamics. *Physical Review* **76** (1949) 769–789.
Relevance. The diagrammatic formulation of QED — with Tomonaga (1946) and Dyson (1949), the apparatus by which the point electron's infinities were tamed into the most precise theory in science. Cited in §25 at the hinge of the Q4 story: the formalism that made the point electron *workable* is precisely what allowed the question of why it is a point to sleep for seventy years. First cited in §25.

Feynman, R. P. The development of the space-time view of quantum electrodynamics (Nobel lecture). *Science* **153** (1966) 699–708.
Relevance. Primary source for Wheeler's one-electron universe (the 1940 telephone call), engaged in §37 as the closest historical ancestor of identity-by-uniqueness — and for the foundational period of QED whose sign-rule credit Part VII states. First cited in §37.

Feynman, R. P., & Vernon, F. L. The theory of a general quantum system interacting with a linear dissipative system. *Annals of Physics* **24** (1963) 118–173.
Relevance. The influence functional: the exact form of a dynamics from which a sector has been traced out — the mathematical key to openness, published eight years after Einstein's death. Cited in §45 as the first of the tools without which the second half of the unification dream was inaccessible; its deployment on the radiation field is GG-A5-GDOS's quantitative closure, imported in §34. First cited in §45.

Green, M. B. & Schwarz, J. H. Anomaly cancellations in supersymmetric $D = 10$ gauge theory and superstring theory. *Physics Letters B* **149** (1984) 117–122.
Relevance. The original modified-Bianchi-identity mechanism, of which the cohort's BI-6 is the six-dimensional descent — the shared machinery acknowledged in §38.1 and §38.5. First cited in §38.1.

Green, M. B., Schwarz, J. H. & Witten, E. *Superstring Theory, Vols. 1–2.* Cambridge University Press, Cambridge (1987).

Relevance. The standard reference for superstring compactification and anomaly cancellation; the framework against which §38 draws its contrast, credited there without reluctance. First cited in §38.5.

Hanneke, D., Fogwell, S. & Gabrielse, G. New measurement of the electron magnetic moment and the fine structure constant. *Physical Review Letters* **100** (2008) 120801.
Relevance. The one-electron quantum cyclotron measurement that held the record for fifteen years before Fan et al. (2023): a single electron, suspended for months, interrogated at the level of parts in 10^{13}. Cited in §39 (P3) as part of the experimental lineage this paper bets on continuing — each generation of traps a fresh chance to find the structural deviation the framework forbids. First cited in §39.

Hughes, R. J. & Deutch, B. I. Electric charges of positrons and antiprotons. *Physical Review Letters* **69** (1992) 578–581.
Relevance. The charge-sum bound $|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$, from Rydberg-energy and cyclotron-frequency ratios, quoted in §23: in the conjugate-readout picture the charge flip is definitional (reversed winding), so the bound tests whether the mirror is exact. First cited in §23.

Harari, H. A schematic model of quarks and leptons. *Physics Letters B* **86** (1979) 83–86.
Relevance. The rishon model: the most economical preon construction, engaged in §37 as the compositeness tradition at its best — and the cleanest illustration of the mass paradox that the non-spatial relocation of structure dissolves. First cited in §37.

Helgason, S. *Differential Geometry, Lie Groups, and Symmetric Spaces.* Academic Press, New York (1979).
Relevance. Standard reference for the symmetric-space geometry of $\mathbb{C}P^{N-1}$ underlying the gate-action computation reproduced in Appendix E.2 (with Witten, 1982): the Fubini–Study metric, the isometry group, and the geodesic structure between critical points are all standard material here. For the student, the relevant chapters are those on compact symmetric spaces — $\mathbb{C}P^2$ is the simplest non-trivial example, which is part of why the family stratum's Morse theory is tractable at all. First cited in §E.2.

Hulse, R. A., & Taylor, J. H. Discovery of a pulsar in a binary system. *The Astrophysical Journal* **195** (1975) L51–L53.
Relevance. The binary pulsar PSR B1913+16, whose measured orbital decay has followed the general-relativistic quadrupole prediction for five decades to a few parts in 10^3 — the first empirical proof that gravitational radiation drains orbital energy. Cited in §34 as the empirical anchor of the inspiral half of the synchrotron/inspiral worked example imported from GG-A5-GDOS. First cited in §34.

Jordan, R., Kinderlehrer, D., & Otto, F. The variational formulation of the Fokker–Planck equation. *SIAM Journal on Mathematical Analysis* **29** (1998) 1–17.
Relevance. The discovery that dissipative dynamics is gradient flow — descent of a free-energy functional in a geometry on the space of states — inaugurating the mathematics in which this

paper's landscapes, basins, and descents are written. Cited in §45: the language of the answer to the six questions did not exist until the century was nearly over. First cited in §45.

Kachru, S., Kallosh, R., Linde, A. & Trivedi, S. P. de Sitter vacua in string theory. *Physical Review D* **68** (2003) 046005.
Relevance. The KKLT construction — the technical centerpiece of the string landscape: metastable de Sitter vacua by the 10^{500}. Cited in §38.2 as the sharpest form of the position this paper's anti-landscape bet opposes: where moduli are dials, constants are environmental; where the ledger is five integers, constants are theorems. One of the two positions will lose to data. First cited in §11.1.

Kaluza, T. Zum Unitätsproblem der Physik. *Sitzungsberichte der Preussischen Akademie der Wissenschaften* (1921) 966–972.
Relevance. The original fifth dimension: gravity in five dimensions containing Maxwell's theory — the first proof-of-concept that electromagnetism can be geometry. The GG-6 bulk is this insight with the fatal flaw repaired: Kaluza's extra dimension was *spatial*, with a radius nothing fixed; the GG-6 directions are scale and phase, with integers where the dials were (§38.2; Appendix G). Read it to see how close 1921 came. First cited in §33.1.

Klein, O. Quantentheorie und fünfdimensionale Relativitätstheorie. *Zeitschrift für Physik* **37** (1926) 895–906.
Relevance. The compactification of Kaluza's dimension and the origin of charge quantization from circular topology: momentum around a compact circle comes in integers. That single mechanism — charge as quantized holonomy momentum — survives intact into the present framework's phase circle S^1_θ (§32; Table 10), making Klein's paper the direct ancestor of this paper's answer to "why is charge quantized?" First cited in §31.

Kobayashi, M. & Maskawa, T. CP-violation in the renormalizable theory of weak interaction. *Progress of Theoretical Physics* **49** (1973) 652–657.
Relevance. The six-quark insight: with fewer than three families the weak mixing matrix carries no physical CP phase, so observed CP violation demands a third family — predicted here four years before the tau and twenty-two before the top. Leg (L1) of the $N = 3$ derivation (Appendix E.1) is this argument run under MSMF; the student should read the original to see a family of matter conjured from one phase that would not go away. First cited in §E.1.

Kuhn, T. S. *The Structure of Scientific Revolutions.* University of Chicago Press, Chicago (1962).
Relevance. The account of how frameworks replace one another: by dissolving standing anomalies and surviving the tests the old framework could not name. Cited in §45 to discipline this paper's own largest claim — a paradigm shift is a verdict the community renders, not a thing a paper declares; what a paper can do is qualify, by naming its anomalies and pre-registering its falsifiers, which is what Part VIII is for. First cited in §45.

Kusch, P. & Foley, H. M. The magnetic moment of the electron. *Physical Review* **74** (1948) 250–263.

Relevance. The discovery that $g \neq 2$: the electron's moment exceeds Dirac's value by a part in a thousand. Together with Schwinger (1948), which explained the excess as $\alpha/2\pi$, this opened the dressing-versus-structure distinction on which the entire form-factor argument of §29 rests: the anomaly is the vacuum's contribution, not the electron's size — a lesson first taught here. First cited in §25.

Lamb, W. E. & Retherford, R. C. Fine structure of the hydrogen atom by a microwave method. *Physical Review* **72** (1947) 241–243.
Relevance. The Lamb shift: the vacuum visibly dressing a bound electron, and the experimental detonator of modern QED. Cited in §25 as the partner discovery to Kusch & Foley (1948) — the pair of 1947–48 measurements that forced the renormalization program and thereby fixed, for seventy years, the working answer to Q4: *calculable dressing around an unexplained point.* First cited in §25.

Larmor, J. On the theory of the magnetic influence on spectra; and on the radiation of moving ions. *Philosophical Magazine*, Series 5, **44** (1897) 503–512.
Relevance. The original formula for the power radiated by an accelerated charge — the oldest quantitative statement that acceleration in the gauge sector is paid for in radiation. Cited in Reading 34.1 and §34: Larmor's loss is the dissipative channel of motion, the one place open-system language properly attaches to a moving electron. First cited in §34.

Lindblad, G. On the generators of quantum dynamical semigroups. *Communications in Mathematical Physics* **48** (1976) 119–130.
Relevance. The general form of Markovian open-system dynamics — dissipative quantum evolution made mathematically exact. Cited in §43 as the century's great near-miss: the machinery of descent existed from 1976, but was filed under applied decoherence rather than foundations, which is precisely the closed-system blind spot that kept ground-state-ness unavailable as an answer to the six questions until the open-system shift of GDOS. First cited in §43.

Jarlskog, C. Commutator of the quark mass matrices in the standard electroweak model and a measure of maximal CP nonconservation. *Physical Review Letters* **55** (1985) 1039–1042.
Relevance. The basis-independent measure of CP violation — the invariant J_{CKM} whose non-vanishing is the empirical input of leg (L1) (Appendix E.1). Jarlskog's construction matters methodologically for this paper: it converts "CP is violated" from a parameterization-dependent statement into a single number an experiment can measure and a counting argument can consume. First cited in §16.

Lorentz, H. A. *The Theory of Electrons and Its Applications to the Phenomena of Light and Radiant Heat.* Teubner, Leipzig (1909).
Relevance. The canonical extended-electron theory whose stability problem (§25) defined Q4's classical crisis. First cited in §25.

Maldacena, J. The large N limit of superconformal field theories and supergravity. *Advances in Theoretical and Mathematical Physics* **2** (1998) 231–252.

Relevance. AdS/CFT: the modern holographic dictionary between bulk gravity and boundary field theory. Cited in §38.1 as shared machinery — the bulk-to-boundary projection grammar that GG-Theory deploys with opposite constitutional commitments (non-spatial directions, zero moduli, an open-system boundary law). The student who knows AdS/CFT will recognize the radial-direction-as-RG reading; the framework's departure is to make that reading constitutional. First cited in §38.1.

Maxwell, J. C. A dynamical theory of the electromagnetic field. *Philosophical Transactions of the Royal Society of London* **155** (1865) 459–512.
Relevance. The unification of electricity, magnetism, and light — the first great field theory, and the system of equations that Chain (B) re-derives from the bulk gauge connection (Appendix G.2). In this paper's arc Maxwell plays the role Newton plays for Chain (A): the classical summit that the six-dimensional geometry must reproduce exactly before it may claim anything new — and does. First cited in §33.1.

Mermin, N. D. What's wrong with this pillow? *Physics Today* **42**(4) (1989) 9–11.
Relevance. The source of "shut up and calculate" (often misattributed to Feynman; Mermin himself later documented the attribution), quoted in §43 as the emblem of the professional attitude that filed the questions of this paper under metaphysics for a century. First cited in §43.

Millikan, R. A. On the elementary electrical charge and the Avogadro constant. *Physical Review* **2** (1913) 109–143.
Relevance. The oil-drop measurement: charge comes in integer multiples of one unit, measured drop by drop. This is Q1's "and the same charge" made empirical — the quantization that §12.2 derives from compact holonomy and that Klein (1926) first explained topologically. The student should notice what Millikan could not ask: *why* integers? The answer waited for a compact phase dimension. First cited in §2.

Morel, L., Yao, Z., Cladé, P. & Guellati-Khélifa, S. Determination of the fine-structure constant with an accuracy of 81 parts per trillion. *Nature* **588** (2020) 61–65.
Relevance. The rubidium recoil determination of α; together with Parker et al. (2018) defines the $> 5\sigma$ experimental discrepancy that kill criterion F4 is phrased to respect. First cited in §32.

Morse, M. *The Calculus of Variations in the Large.* American Mathematical Society Colloquium Publications, Vol. 18, Providence (1934).
Relevance. The founding monograph of Morse theory: critical points of a function encode the topology of the space it lives on. The entire landscape ontology of this paper — basins, saddles, gates, the index-0/2/4 skeleton of $\mathbb{C}P^2$ (Appendix D.1) — is Morse's mathematics deployed as physics, with the generations as critical points and their masses as critical values. First cited in §D.1.

Neddermeyer, S. H. & Anderson, C. D. Note on the nature of cosmic-ray particles. *Physical Review* **51** (1937) 884–886.
Relevance. The muon: a particle with the electron's charge and spin but two hundred times its mass, found in cosmic rays and wanted by no theory — the original "who ordered that?" In this

paper's terms, Neddermeyer and Anderson discovered the depth-1 basin (§15) eighty-nine years before the landscape that houses it was drawn; Q3 begins on these three pages. First cited in §15.

Newton, I. *Philosophiæ Naturalis Principia Mathematica.* Royal Society, London (1687).
Relevance. The inverse-square law of gravitation and the equation of motion — the two endpoints of Chain (A) (Appendix G.1). The GG-Theory claim under Q5 is that Newton's law and Coulomb's law are one law read on two curvatures; the Principia supplies the gravitational half of that sentence three centuries in advance, and the parallel-chain derivation is, in a precise sense, the Principia's $1/r^2$ recomputed from six dimensions. First cited in §33.1.

Noether, E. Invariante Variationsprobleme. *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse* (1918) 235–257.
Relevance. Symmetries make currents: the theorem behind both conserved four-currents of Appendix G.4 — stress–energy from translations, electric current from U(1) — and hence behind ingredient (iii) of the Newton–Coulomb twinning. Every Ward identity in the cohort is Noether's theorem boundary-transported; the student should meet it in the original, where it is purer than in any textbook. First cited in §G.4.

Okun, L. B. & Zeldovich, Ya. B. Paradoxes of unstable electron. *Physics Letters B* **78** (1978) 597–600.
Relevance. The theoretical anatomy of electron decay: any charge-nonconserving instability, made consistent with the photon's masslessness, forces pathological longitudinal-photon emission — decay is not merely unobserved but theoretically expensive. Cited in §13.1 as the sharpest standard-physics companion to the Borexino search: even the loopholes have paradoxes. The GG-Theory statement is stronger still — no gate exists at all — and P1 inherits both lineages. First cited in §13.1.

Parker, R. H., Yu, C., Zhong, W., Estey, B. & Müller, H. Measurement of the fine-structure constant as a test of the Standard Model. *Science* **360** (2018) 191–195.
Relevance. The cesium recoil determination of α; the second pole of the Rb/Cs discrepancy noted in §32 and F4. First cited in §32.

Particle Data Group. Review of Particle Physics. *Progress of Theoretical and Experimental Physics* **2024** (2024) 083C01.
Relevance. The standard compilation for lepton properties and compositeness listings consumed in Part VIII and Appendix H. First cited in §15.

Perl, M. L., et al. Evidence for anomalous lepton production in e^+e^- annihilation. *Physical Review Letters* **35** (1975) 1489–1492.
Relevance. The tau: the third copy of the electron, found at SPEAR in anomalous $e\mu$ events. It completed the pattern Q3 asks about — and, by being the *last* such discovery despite five decades of energy frontier since, it wrote the other half of the question: why does the ladder stop? §15 houses it at depth 0; Appendix E counts why nothing sits above it. First cited in §15.

Pati, J. C. & Salam, A. Lepton number as the fourth "color". *Physical Review D* **10** (1974) 275–289.

Relevance. The opening of the compositeness era: quarks and leptons unified, with substructure ("preons") as the suggested mechanism beneath the pattern. The tradition it launched — through Harari (1979); Shupe (1979) — is the structural bet against which §37 and Table 5 score this paper's opposite wager: pattern from connection data rather than from constituents. First cited in §37.

Pauli, W. Über den Zusammenhang des Abschlusses der Elektronengruppen im Atom mit der Komplexstruktur der Spektren. *Zeitschrift für Physik* **31** (1925) 765–783.

Relevance. The exclusion principle — announced before spin itself, as a "classically non-describable two-valuedness." It is the bridge from Q1 to chemistry: identity plus exclusion equals the periodic table, which is why §46 can say that the sameness of the electron is the reliability of the world. The two-valuedness Pauli could not describe classically is the quaternionic double cover of §12.3. First cited in §2.

Pauli, W. The connection between spin and statistics. *Physical Review* **58** (1940) 716–722.

Relevance. The spin-statistics theorem: half-integer spin forces antisymmetry, integer spin symmetry, from relativity and positivity alone. Cited in §11.1 as the deepest layer of the standard identity story — not only are field quanta identical, the *way* they are identical is forced by their spin. The present framework inherits the theorem on the boundary and supplies the layer beneath it: why spin-$\frac{1}{2}$ was selected at all. First cited in §11.1.

Poincaré, H. Sur la dynamique de l'électron. *Rendiconti del Circolo Matematico di Palermo* **21** (1906) 129–176.

Relevance. Source of the Poincaré stresses — the non-electromagnetic glue an extended classical electron required — declared "unemployed" by the basin-level reading of the mass in §28. First cited in §25.

Randall, L. & Sundrum, R. A large mass hierarchy from a small extra dimension. *Physical Review Letters* **83** (1999) 3370–3373.

Relevance. The warped-throat geometry whose diagram the GG-6 bulk recapitulates with a different reading of the radial axis (RG scale, not space); the lineage credited in §38.1 and Fig. 1's visual vocabulary. First cited in §38.1.

Schrödinger, E. Quantisierung als Eigenwertproblem (Erste Mitteilung). *Annalen der Physik* **79** (1926) 361–376.

Relevance. The wave equation of the boundary calculus, written down in 1926 without a derivation from anything deeper. Cited in §45 for the centenary that frames this paper: one hundred years later the companion papers derive the boundary calculus — equation and rule — as theorems of the OGGEP reduction. First cited in §45.

Schwinger, J. On quantum-electrodynamics and the magnetic moment of the electron. *Physical Review* **73** (1948) 416–417.

Relevance. The first radiative correction $a_e = \alpha/2\pi$: the founding result of the QED dressing whose distinction from *structure* carries the form-factor argument of Appendix F, and part of the sign-rule-era credit stated in §33. First cited in Appendix F.

Shupe, M. A. A composite model of leptons and quarks. *Physics Letters B* **86** (1979) 87–92.
Relevance. The independent twin of Harari (1979): the same two-preon economy discovered simultaneously, which is itself instructive — the rishon counting was so natural that two people found it at once. Cited in §37 as part of compositeness at its best, before the mass paradox and the null searches closed the road that this paper's non-spatial relocation reopens at no experimental cost. First cited in §37.

Sommerfeld, A. Zur Quantentheorie der Spektrallinien. *Annalen der Physik* **51** (1916) 1–94.
Relevance. The birth of α: introduced as the relativistic fine-structure parameter of hydrogen, it became the dimensionless riddle of the century — Feynman's "magic number." Cited in §32: the constant Sommerfeld introduced as an input is, in Appendix C.3, the dyadic attractor coordinate $2^J + N^2$, and the century-long question "why 137?" receives an arithmetic answer with a declared status. First cited in §32.

Stern, O. & Gerlach, W. Der experimentelle Nachweis der Richtungsquantelung im Magnetfeld. *Zeitschrift für Physik* **9** (1922) 349–352.
Relevance. The two spots: space quantization measured three years before spin was proposed — the experiment that showed the electron's angular degree of freedom is binary. In this paper's terms the two spots are the boundary readout of the quaternionic doublet (§12.3); the student should hold the 1922 photograph next to Eq. (27) and note that the number two traveled ninety years to find its algebra. First cited in §12.3.

Stoney, G. J. Of the "electron," or atom of electricity. *Philosophical Magazine*, Series 5, **38** (1894) 418–420.
Relevance. The naming of the electron — proposed as the natural unit of electricity from Faraday's electrolysis, before any particle had been seen. Cited in §2: the concept preceded the discovery by a generation, and the unit Stoney abstracted from chemistry is the same quantized e that §12.2 derives from holonomy — a hundred and thirty years from electrolysis jars to winding integers. First cited in §2.

Susskind, L. The anthropic landscape of string theory. arXiv:hep-th/0302219 (2003).
Relevance. The canonical statement of the landscape position — the values of the constants as environmental selections — against which §37 and §38.2 set the anti-landscape bet of the integer ledger. First cited in §37.

't Hooft, G. Naturalness, chiral symmetry, and spontaneous chiral symmetry breaking. In *Recent Developments in Gauge Theories* (Cargèse 1979), NATO Advanced Study Institutes Series B59, Plenum Press, New York (1980) 135–157.
Relevance. Anomaly matching and naturalness: the consistency conditions any composite model of light fermions must satisfy, and the formal statement of why a bound electron far lighter than

its binding scale is unnatural — the mass paradox cited in §37. This paper's escape is structural: with the electron's "structure" relocated to non-spatial connection data, there is no binding scale to be unnatural about. First cited in §37.

Thomson, J. J. Cathode rays. *Philosophical Magazine*, Series 5, **44** (1897) 293–316.
Relevance. The identification of the electron: cathode rays deflected as a single charged corpuscle with a universal e/m, measured the same in every gas and from every cathode — the first experimental hint of Q1, visible in the discovery paper itself. The century this paper's title counts begins here, and so does the irony its preface addresses: the particle was identified *by* the very sameness that then went unexplained for a hundred and twenty-nine years. First cited in §2.

Tomonaga, S. On a relativistically invariant formulation of the quantum theory of wave fields. *Progress of Theoretical Physics* **1** (1946) 27–42.
Relevance. The first covariant formulation of renormalized QED, developed in wartime isolation. With Feynman (1949) and Dyson (1949) it forms the trio cited at §25's hinge: the machinery that made the point electron calculable. The student should know all three names; the present paper's claim is not that their construction was wrong but that it answered "how to live with the point" while "why the point" waited. First cited in §25.

Uhlenbeck, G. E. & Goudsmit, S. Ersetzung der Hypothese vom unmechanischen Zwang durch eine Forderung bezüglich des inneren Verhaltens jedes einzelnen Elektrons. *Die Naturwissenschaften* **13** (1925) 953–954.
Relevance. The proposal of electron spin, whose superluminal-surface paradox for any spatially spinning model is dissolved by the double-cover reading of §28. First cited in §25.

Van Dyck, R. S., Jr., Schwinberg, P. B. & Dehmelt, H. G. New high-precision comparison of electron and positron g factors. *Physical Review Letters* **59** (1987) 26–29.
Relevance. The Penning-trap comparison $(g_{e^+} - g_{e^-})/g = (-0.5 \pm 2.1) \times 10^{-12}$ — among the sharpest null results in physics, quoted in §23. In the readout picture the null is not a symmetry holding between two objects but the absence of a second object; a confirmed asymmetry would kill the reading of Part V before it killed CPT. First cited in §23.

Weinberg, S. *The Quantum Theory of Fields, Vol. 1: Foundations.* Cambridge University Press, Cambridge (1995).
Relevance. The canonical modern treatment of particle identity as field-quantum indistinguishability and of Wigner's representation classification — the standard-physics position on Q1, credited at full strength in §11.1 and §37. First cited in §20.

Weyl, H. Gravitation und Elektrizität. *Sitzungsberichte der Königlich Preußischen Akademie der Wissenschaften (Berlin)* (1918) 465–480.
Relevance. The first attempt to geometrize electromagnetism — on the *scale* direction, as a local rescaling invariance — felled by Einstein's objection that histories would imprint on atomic spectra. Cited in §44 as the failure the framework diagnoses rather than merely survives: scale *is* geometric, but it is gravity's dimension; electromagnetism's is the phase, where Weyl himself moved it in 1929. First cited in §44.

Weyl, H. Elektron und Gravitation I. *Zeitschrift für Physik* **56** (1929) 330–352.
Relevance. The gauge principle in its modern form: local phase invariance demands the electromagnetic connection — conceived, fittingly, in a paper joining the electron to gravitation. Step B1 of Chain (B) (Appendix G.2) is Weyl's argument verbatim; AX-2's composite connection is Weyl's program completed in the direction he pointed: gauge and geometry as one object, with the electron riding both. First cited in §44.

Wigner, E. P. On unitary representations of the inhomogeneous Lorentz group. *Annals of Mathematics* **40** (1939) 149–204.
Relevance. The classification within which spin-$\frac{1}{2}$ is, for the Standard Model, an unexplained choice — the precise sense in which Q1's "why those values" includes the representation, answered geometrically in §12.3. First cited in §11.1.

Witten, E. Supersymmetry and Morse theory. *Journal of Differential Geometry* **17** (1982) 661–692.
Relevance. The classical source for instanton counting between Morse critical points — the mathematical machinery behind the Bogomolnyi gate actions $S = \pi k$ quoted in **Figure 7** and Eq. (7), as deployed upstream by GG-A6-GRIP and GG-A9-SM. First cited in §15.

Yang, C. N. & Mills, R. L. Conservation of isotopic spin and isotopic gauge invariance. *Physical Review* **96** (1954) 191–195.
Relevance. The non-Abelian gauge field: Weyl's principle generalized to internal symmetry spaces, the template of the entire Standard-Model gauge sector. Cited alongside Weyl (1929) in Appendix G.2: the bulk gauge factor whose unbroken commutant is this paper's photon is a Yang–Mills object, and the "two curvatures" sentence of Eq. (12) is the Yang–Mills curvature standing beside Riemann's. First cited in §G.

Zeeman, P. On the influence of magnetism on the nature of the light emitted by a substance. *Philosophical Magazine*, Series 5, **43** (1897) 226–239.
Relevance. The magnetic splitting of spectral lines — the electron weighed inside the atom in the same year Thomson weighed it in the beam, with Lorentz's analysis extracting the same e/m. Cited in §2 as the second leg of the 1897 discovery: from its first year the electron was *one* particle seen two ways, a premonition of Q1 that this paper finally converts into a theorem. First cited in §2.