Persistence Dynamics

The Internal Geometry of Dissipative-Autopoietic Systems

Raimo van der Klein
Founder, Encounter (encounter.bio)
Hoofddorp, Netherlands
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Abstract

Persistence Dynamics specifies the internal geometry of systems that maintain themselves by running. Two operations (hold and cross), each either active or latent, produce four regimes (Potentiality, Construction, Encounter, Conservation) that any persisting system traverses in a forced order. The traversal closes under one structural condition. That condition has a single solution at $d = 1/\phi$, where ϕ is the golden ratio. Closure at one level projects upward as one of two axes of a cycle at the level above, with Pythagorean conservation across the projection. The geometry holds across substrates: cell, clinical trial, organisation, career. The work positions itself as the internal kinematics of the dissipative-autopoietic systems named by Schrödinger, Prigogine, and Maturana and Varela, and as a falsifiable account of how such systems persist and recurse across scales.

Keywords: dissipative systems, autopoiesis, persistence, four regimes, golden ratio, scale invariance, structural geometry

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1. The unfinished problem

In 1944, Erwin Schrödinger asked how a living thing keeps its structure when the universe around it runs toward disorder. *What is Life?* posed the puzzle in thermodynamic terms. A system that persists must draw order from its environment faster than its internal order decays. Schrödinger proposed that life feeds on what he called *negative entropy*. He named the puzzle without solving it.

Ilya Prigogine made the thermodynamics rigorous twenty-five years later. His work on dissipative structures showed that certain physical systems, held far from thermodynamic equilibrium by a steady flow of energy and matter, organise themselves into stable patterns. The hurricane. The Bénard convection cell. The candle flame. The metabolising organism. All exist only as long as flow continues. Cut the flow and the structure dissolves. The Nobel Prize in Chemistry followed in 1977.

Humberto Maturana and Francisco Varela approached the same territory from biology. Their question was what distinguishes a *living* dissipative system from a merely physical one. Their answer was *autopoiesis*. A living system produces the components that produce it. The cell makes the membrane that makes the cell. The boundary between organism and environment is itself produced by the organism. Their 1972 book gave the self-referential closure that distinguishes biology from physics.

Three lineages, three contributions. Schrödinger named the thermodynamic requirement. Prigogine specified the conditions under which dissipative structures form. Maturana and Varela specified the closure that distinguishes life from non-living dissipation. Together they describe a class of systems and

the conditions under which the class is possible.

None of them specified the cycle that runs inside such a system.

The internal kinematics was left as content for empirical study, one domain at a time. Developmental biology produced its four-stage models. Immunology produced its priming-effector-contraction-memory sequence. Project management produced its initiation-execution-closure cycles. Organisational change produced its many four-quadrant models. Each tradition observed a four-phase shape within its own substrate. No tradition derived the shape from structural first principles.

This paper derives it. The two operations, the four regimes, the forced order, the closure condition, and the recursion across scales are stated as structural claims with formal content. Persistence Dynamics is the name of the resulting account.

The paper proceeds as follows. Section 2 derives the two operations from minimal conditions on a persisting system. Section 3 derives the four regimes from the two-state binary on the two operations. Section 4 derives the forced order in which the regimes must run, via two independent arguments that converge on the same sequence. Section 5 derives the closure condition, the rate constants that follow from it, the Pythagorean conservation across the projection, and the damping identity that makes the structure measurable. Section 6 derives the recursion: how a closed cycle becomes one axis at the level above, with Pythagorean conservation across the projection. Section 7 states the five prerequisites a system must satisfy for the cycle to be readable as a coherent process. Section 8 names what Persistence Dynamics contributes to the lineages it builds on and to cross-domain work generally. Section 9 places the account in relation to other contemporary frameworks. Section 10 surfaces open questions. Section 11 lists the empirical signatures that would disconfirm the account.

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2. The two operations

A system that persists by running must perform two operations. It must hold, and it must cross. These are the minimal primitives. Everything else in the account derives from them.

2.1 Hold

To hold is to retain. The hold operation is what a system does with what it has accumulated: it keeps that material present, configured, and available for use. Hold maintains the continuity of the system with its own past. The cell membrane holds the cytoplasm. The institution holds its method between projects. The composer holds the key signature across an entire movement. Without hold, no material from a prior moment is available at the present one.

Hold costs work. A membrane holding a concentration gradient against diffusion is doing thermodynamic work continuously. An institution holding its method against environmental drift is doing organisational work continuously. Persistence requires this expenditure. A system that stops paying the cost of holding ceases to maintain its own state.

2.2 Cross

To cross is to engage. The cross operation reaches across the boundary between the system and what is beyond it: another system, an environment, a target, a contingent reality. Cross is what makes the system continuous with what is to come. The cell membrane releases signals across itself. The institution

publishes decisions. The composer resolves a dissonance into the next chord. Without cross, no material from the present moment becomes substrate for what follows.

Cross also costs work, and it commits the system. A cross commits to one engagement at the cost of every other engagement the system could have entered instead. The system that crosses gives up optionality in exchange for actuality.

2.3 Why exactly two

The argument for exactly two operations rests on two considerations.

First, hold and cross are the minimal pair that distinguishes persistence from its two adjacent failure modes. A system that only holds is static configuration: it retains material but engages nothing, and it does not run. A system that only crosses is pure event: it produces no accumulated state and has no internal continuity. Persistence requires both operations active in alternation, or it is one or the other of these failures.

Second, hold and cross are the two structural moves available with respect to time. Hold acts on the system's accumulated state, which is the time-reversed component of where the system is now. Cross acts on the system's gradient toward its next configuration, which is the time-forward component. These are the two halves of the system's instantaneous state, and a persisting system requires both to be operational.

Any candidate for a third operation, on examination, reduces to a configuration of hold and cross at different scales or to a sub-phase within one of them. Maintenance is hold while crossing against environment. Reproduction is cross into substrate that then holds. Selection is cross followed by hold. The two operations are a complete basis.

2.4 Active and latent

At any moment, each operation is in one of two states. It is either active (doing work right now) or latent (configured but not currently engaged). Latent is not absent: a latent hold is a hold operation in standby, available to be activated; a latent cross is a cross operation that is set up but not yet committing.

The active/latent distinction is binary. An operation either contributes to the system's current work or it does not. Partial activation is still activation. There is no third state at the level of the operation itself.

Two operations with two states each give four configurations. Each configuration is a regime.

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3. The four regimes

Each configuration of the two operations defines a regime. The four regimes are the four discrete combinations of the two binary state variables. Each is structurally distinct from the others, and each corresponds to a canonical dynamical-systems primitive.

Regime	Hold	Cross	Type
Potentiality	active	active	Capacitor
Construction	latent	active	Factory
Encounter	latent	latent	Reactor
Conservation	active	latent	Homeostat

The four type names are not analogies imported from engineering. Each is the canonical structure of its regime's bit-state, and each has its own observables, equations, and characteristic failure modes.

3.1 Potentiality: the capacitor

Both operations active. The system has gathered material against a threshold and configured a release mechanism. Below the threshold, the loading signal acts as a brake. Above the threshold, the same signal becomes the trigger and the accumulated material releases as a discrete event.

The dynamical signature of Potentiality is the threshold sign-flip. A capacitor is what makes continuous flow into discrete rhythm. Without a threshold, inflow and outflow track each other continuously and the system has no clock. With a threshold, the inflow accumulates until release, then drains until reloading begins. Every periodic cycle Persistence Dynamics has examined traces its clock back to a capacitor somewhere in its lineage.

Examples that sit in this regime: a lymph node loading antigen up to the threshold for T-cell priming; an unwritten manuscript that the writer has worked out internally but has not yet committed to the page; a team that has gathered all the information and is one conversation away from a binding decision.

Failure modes: releasing before enough has gathered (premature firing); failing to release after gathering has saturated (stalled load).

3.2 Construction: the factory

Hold latent, cross active. The accumulated material has been released; the system is committed to a forward direction; selection runs across candidates and one is chosen; the chosen form is built. The dynamical signature of Construction is parallel-tracked steady flow with a selection gate: throughput on the lines, differentiation across tracks, yield at the gate.

Construction has a property unique among the four regimes. Of the four, only Construction takes a symmetric field of candidates and produces an ordered output. A capacitor's output is a scalar (the total accumulated). A reactor's output is symmetric in its inputs (mutual reactions, no before-or-after relation between them). A homeostat's output is an unordered distribution. Only Construction's competitive selection manufactures a before/after relation that did not exist in the input. Every temporal arrow downstream of a cycle traces back to a Construction event. Sequence is built in this regime.

Examples: an immune clone expanding to a chosen specificity; a draft becoming a document; an evolutionary lineage selecting against a fitness landscape; a protocol specified in enough detail that someone could actually run it.

Failure modes: selection never completes (stuck competition); the chosen form does not fit what it must engage (wrong product).

3.3 Encounter: the reactor

Both operations latent. The built form is in contact with what it was made for. The system holds nothing back and reaches for nothing further; the contact itself is the work. The dynamical signature of Encounter is many parallel reaction sites running concurrently, each with its own rate, yield, and balance. Reach matters more than strength in this regime. A single sub-position where coverage is missing cancels gains made everywhere else.

Encounter is the regime where most clinical trials and most product launches succeed or fail. It is also the regime that takes longest to read accurately, because both operations being latent looks like nothing happening, while what is actually happening is the meeting that determines whether the prior three regimes did their work correctly.

Examples: a T-cell engaging a tumour antigen; a product meeting its market; a treatment meeting its disease; an audience meeting a performance.

Failure modes: the meeting does not arrive (no contact); the meeting arrives at the wrong target (mistargeting); the meeting cannot end (locked engagement).

3.4 Conservation: the homeostat

Hold active, cross latent. What survived the encounter is being kept; what is finished is being released; the substrate for the next round is being prepared. The dynamical signature of Conservation is multi-layer maintenance with drift-detection feedback. The system holds a setpoint, watches for departure, applies correction, and the correcting activity itself produces the perturbation that initiates the next cycle.

Conservation carries two simultaneous responsibilities. Hold what worked. Release what is done. Both at once. A homeostat that holds everything becomes rigid and cannot adapt. A homeostat that releases everything becomes amnesic and cannot accumulate. The work of Conservation is the negotiation between these two failures, and the dual responsibility makes it the hardest regime to read in any actual system.

Examples: a memory T-cell population maintained after antigen clearance; an institutional method retained between projects; the consolidation of memory during sleep; the post-launch sustainment of a product.

Failure modes: nothing is released (over-conservation, rigidity); what should have been kept is dropped (under-conservation, forgetting).

3.5 The four types as the operational test

The capacitor / factory / reactor / homeostat assignment is the operational test for whether a given regime reading is correct. A claimed Potentiality without a threshold and a sign-flip at it is not a Potentiality. A claimed Construction without ranking from a symmetric input is not a Construction. A claimed Encounter without parallel reaction sites is not an Encounter. A claimed Conservation without drift-detection feedback on a setpoint is not a Conservation.

The four types are not labels added to the regimes for clarity. They are the dynamical-systems primitives that fall out of the two-bit state space. Any persisting system examined at the regime level should be identifiable as one of these four, with the corresponding dynamical signature observable in its operation.

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4. The forced order

The four regimes run in one sequence: Potentiality, Construction, Encounter, Conservation, and back to Potentiality. The sequence is forced. Two independent arguments converge on the same order.

4.1 The combinatoric argument

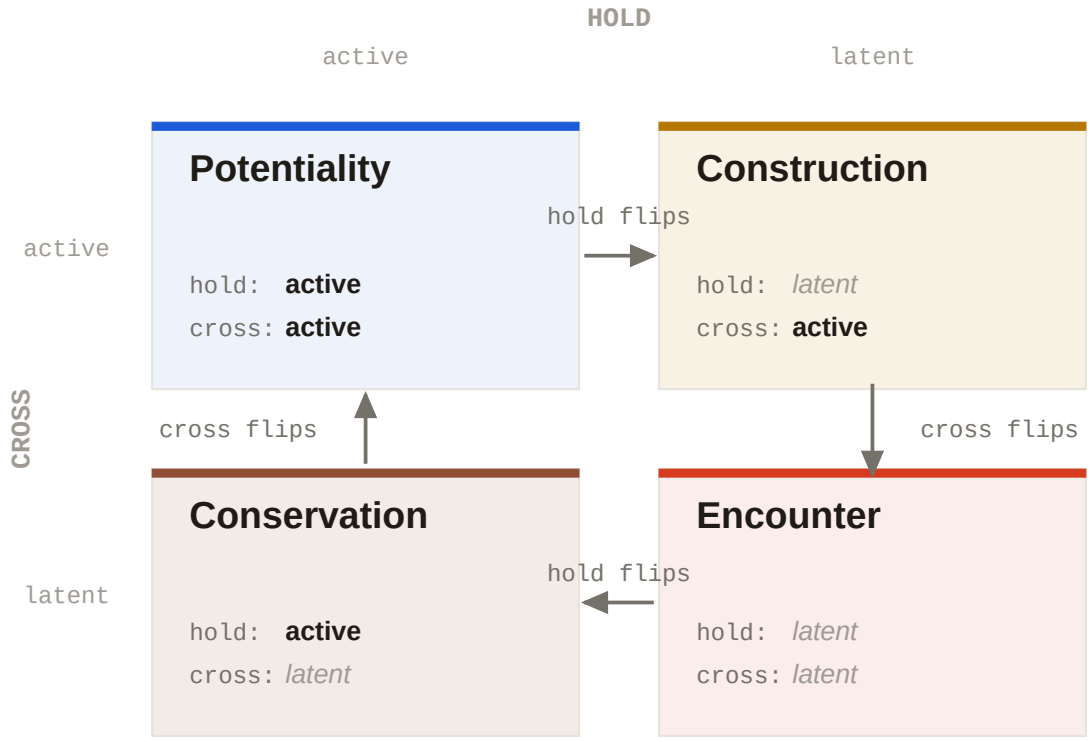
The four regimes are the four states of a two-bit register: hold ∈ {active, latent} and cross ∈ {active, latent}. The cycle visits all four states in sequence and returns to start. The question is whether the order Potentiality → Construction → Encounter → Conservation → Potentiality is the only possible order, or one of many.

Theorem. *The cycle is the unique closed Gray code on two bits, up to direction.*

A *closed Gray code* on *n* bits is a Hamiltonian cycle on the *n*-cube — the graph whose 2^n vertices are the *n*-bit states and whose edges connect states that differ in exactly one bit. For $n = 2$, the 2-cube has four vertices arranged as a square: each vertex is connected to its two neighbours (the two states one bit-flip away) and not to the diagonal opposite (which would require flipping both bits at once).

Proof. A Hamiltonian cycle visits all four vertices exactly once and returns to start. On a 4-cycle graph (a square), there is exactly one such undirected cycle: the perimeter. With a choice of direction, there are two; they are the same cycle traversed clockwise versus counterclockwise. **QED**

The cycle traces the perimeter of the 2-cube. No diagonal is allowed, because no single transition flips both bits at once.



The two-bit state space. Each cell is one regime; each arrow is one transition. Exactly one of the two operations flips state per step. The cycle traces the perimeter; no diagonal is allowed, because no transition flips both bits at once.

The bit-state of each regime, and which bit flips on each transition:

Step	Hold	Cross	Regime	Flipped from previous
0	active	active	Potentiality	—
1	latent	active	Construction	hold
2	latent	latent	Encounter	cross
3	active	latent	Conservation	hold
4 (= 0)	active	active	Potentiality	cross

Any other order would require flipping both bits in at least one transition. A transition that flips both bits skips a regime; it does not pass through a distinct intermediate state. The one-bit-per-step constraint is what makes the cycle visit all four regimes in sequence rather than cutting diagonally across them.

The argument depends only on the combinatoric structure of the state space. It does not depend on what any of the regimes do.

4.2 The substrate-matching argument

The second argument depends on what the regimes do. Each regime produces what the next regime requires as input.

Potentiality discharges accumulated material at threshold. The pooled material that Potentiality releases is what Construction's production lines feed on. A factory without input cannot run; the input arrives from the capacitor's discharge.

Construction produces finished, licensed forms: selected, ranked, ready. These are what Encounter brings into contact with its target. A reactor without reactants cannot run; the reactants arrive from the factory's output.

Encounter produces outcomes, including both what worked and what did not. These outcomes are what Conservation stabilises and stores. A homeostat without something to maintain cannot run; the maintained material arrives from the encounter's residue.

Conservation releases the spent material and consolidates the lessons. The released and consolidated material is what the next round of Potentiality begins to load. A capacitor without substrate to accumulate cannot run; the substrate arrives from the homeostat's output.

The substrate-matching argument gives the same traversal order as the Gray-code argument. Either argument alone would suffice. Together they overdetermine the order.

4.3 The transitions are thresholds

Each transition between regimes is a discrete event. There is a moment at which one regime's work commits and the next regime's work begins. The transitions are not gradual.

This follows from the active/latent binary. A bit-flip is discrete by definition. The system is in regime X until the bit flips, and then it is in regime Y. The transition is a threshold-crossing event, not a continuous traverse through intermediate states.

Four such thresholds exist, one per regime boundary. They are why the cycle is a cycle (a sequence of discrete states linked by transitions) rather than a continuous slide through a phase space. The cycle has rhythm because it has thresholds.

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5. Closure

A round of the cycle is complete when what comes out of Conservation feeds back into Potentiality as the material for the next round. Closure is the structural condition under which this can happen.

Closure is not merely return-to-start. A system that returns to its initial state without producing reusable substrate has run for nothing. Closure has formal content: the cycle's output must be the substrate the cycle's next round requires as input. The cycle gives back what it received, and additionally produces what the next round will run on.

5.1 The closure equation

The cycle does not stand alone. Closure produces substrate that propagates upward to a cycle at the level above, and that cycle's closure produces substrate for the cycle above it. The propagation has a specific scale-composition structure that can be made formal.

Let d be the per-level contraction ratio: a quantity at one level maps to d times that quantity at the next level up. The recursion composes two orders of reach. First order is d: the cycle hands a fraction d of its content upward to the level immediately above. Second order is d^2: that level hands a fraction d of *its* content upward in turn, contributing $d \cdot d = d^2$ of the original unit two levels up. For the recursion to close on a unit (for first-order reach plus second-order reach to sum to a single unit of substrate), the contraction must satisfy the closure equation:

$$d^2 + d = 1$$

Rewrite as a quadratic in d and apply the quadratic formula:

$$d^2 + d - 1 = 0$$

$$d = (-1 \pm \sqrt{(1 + 4)}) / 2 = (-1 \pm \sqrt{5}) / 2$$

Two roots: $d = (\sqrt{5} - 1) / 2 \approx 0.618$ and $d = -(\sqrt{5} + 1) / 2 \approx -1.618$. The negative root has no interpretation as a contraction: a negative scale ratio would reverse orientation at every level-crossing and the cycle could not close on a unit. The positive root is the unique scale ratio at which the recursion closes:

$$d = (\sqrt{5} - 1) / 2 = 1/\phi \approx 0.618$$

where $\phi = (1 + \sqrt{5}) / 2 \approx 1.618$ is the golden ratio.

ϕ is not chosen. It is the unique positive scale ratio at which first-order and second-order reach sum to one unit. Any other ratio breaks the closure. Every appearance of ϕ downstream in the account descends from this single equation at the level-crossing.

5.2 ϕ identities used throughout

The closure equation forces a small set of identities that recur in the derivations that follow. Stated once here for reference:

Identity	Value
$\phi = (1 + \sqrt{5}) / 2$	≈ 1.6180
$1/\phi = (\sqrt{5} - 1) / 2$	≈ 0.6180
$\phi^2 = \phi + 1$	≈ 2.6180
$1/\phi = \phi - 1$	—
$1 - 1/\phi = 1/\phi^2$	≈ 0.3820
$1/\phi + 1/\phi^2 = 1$	—
$\ln \phi$	≈ 0.4812

The last form of the closure equation, $1/\phi + 1/\phi^2 = 1$, is the cycle's structural rate balance: first-order reach plus second-order reach sum to one unit.

5.3 The rate constants

The two terms of $1/\phi + 1/\phi^2 = 1$ set the cycle's natural rates in the closure-derived form.

$1/\phi \approx 0.618$ — first-order reach. The fraction of a cycle's content delivered upward per closure.

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$1/\phi^2 \approx 0.382$ — second-order reach. The fraction reaching two levels up after one closure of each.

Real cycles run faster or slower than these structural rates in ways the substrate determines. The structural rates are the reference against which deviations are read, not a prediction that every observed cycle distributes content in these proportions.

5.4 The Pythagorean conservation across the projection

Closure also has a second formal consequence at the projection from one level to the next.

A running cycle has two crossed diameters. The transactional diameter runs from Potentiality to Encounter, the spatial axis of giving and taking. The generational diameter runs from Construction to Conservation, the temporal axis of loss and birth. The cycle traverses both as it runs.

When the cycle closes, it projects one of its two diameters upward as an axis at the level above. The other diameter remains contained at the cycle's own level as the cycle's internal radial state. For a point on the cycle, the carried and contained components satisfy:

$$carried^2 + contained^2 = R^2$$

where R is the radial coordinate of the cycle. On the canonical orbit $R = 1$ and the conservation reduces to $carried^2 + contained^2 = 1$. Off the canonical orbit $R < 1$, and the system is operating with what the account calls *closure deficit*.

The Pythagorean structure has exactly two quadratic terms because the projection carries two diameters' worth of structural content: one upward as the new axis, one retained as internal state. The conservation is the formal witness of this two-fold split. The directional content of the cycle (the angular position the cycle has reached in its traversal) propagates up; the magnitudinal content (the radial state at the level the cycle is at) stays.

5.5 The carried-contained distinction

There is a subtle structural point inside the conservation law that requires precision. Two different quantities can sit on the *contained* coordinate axis, and they measure opposite things.

The *contained* coordinate, $R \cdot sin(\psi)$ for a sub-angle ψ, measures *arc position*: how far around the orbit the system has moved between two cardinal points. A high contained value means the system is mid-traversal, in transit between regimes. The system is in motion. A cleanly-traversing system has high contained values at the off-cardinal points.

The pathology coordinate is distinct: $\rho_{closure} = 1 - R$, the *closure deficit*. This measures how far the cycle has collapsed inward from the canonical orbit. A high ρ_closure value means the four-regime mass has smeared rather than localised at the cardinals, the angular position is ill-defined, and the closure itself is failing.

Contained and ρ_closure are orthogonal coordinates that measure opposite things. The account must keep them separate. Combining them into a single deviation metric makes both worse, because they pull in opposite directions: contained values are higher in healthy mid-traversal systems, while ρ_closure values are higher in pathological collapsed systems.

The diagnostic logic depends on which coordinate is being read. A system high on contained is moving through its cycle. A system high on ρ_closure is failing at its current level. Each calls for a different class of response.

5.6 The damping identity

For a damped oscillator with damping rate γ and period T, the dimensionless product γT measures the system's logarithmic decrement per period — how much amplitude is lost in one cycle.

The closure-derived form contracts by a factor of $1/\phi$ per nesting level. The natural-log decrement per level is therefore:

$$ln(1 / (1/\phi)) = ln\ \phi \approx 0.4812$$

For a cycle integrating across L nested levels, the per-level log-decrement adds, giving the total damping product:

$$\gamma T = L \cdot ln\ \phi$$

Numerical predictions in the closure-derived form:

L	γT	What it indicates
4	≈ 1.924	One complete four-regime cycle integrating across four nesting levels — the canonical configuration.
5	≈ 2.406	A four-regime cycle with an additional Observer function — one level deeper.
> 2.41	—	The reading is integrating across a meta-scale boundary the structural form does not name.

γT is the framework's most directly measurable prediction. Fit a damped oscillator to a cycling system's observed behaviour, measure γ and T, compute γT, and compare to the predicted structural value. Persistent deviation under controlled conditions falsifies the assignment of L. Persistent deviation across multiple L assignments would falsify the underlying structural form itself.

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6. Recursion

A closed cycle does not sit alone. When a cycle closes, it becomes one element of a larger cycle running at a slower rate above it. In the other direction, every cycle contains smaller cycles running at faster rates inside it. The recursion goes up and down indefinitely; Persistence Dynamics does not commit to a topmost or bottommost level.

The mechanical content of the recursion is what gives the account its predictive force across scales.

6.1 Closure as projection

A cycle, while running, is two-dimensional. It has two crossed diameters and traverses them at angular position θ. The hold/cross pulse that an observer at the level above sees is the projection of this two-dimensional traversal onto one axis.

When the cycle closes, from one level up it is no longer a cycle. It is a line. One degree of freedom that pulses between latent and active. Closure is a projection: it drops a dimension and hands one upward. The cycle becomes an axis.

The axis is necessarily directed. The angular variable θ that the cycle traverses carries an arrow (Potentiality, Construction, Encounter, Conservation, back to Potentiality). The radial variable ρ does not carry an arrow. The projection carries the directed quantity. The axis that propagates upward inherits the cycle's arrow: it pulses between latent and active in the direction of the cycle's traversal.

Going in the other direction, any axis at the level above, unpacked one level down, is itself a closed four-regime cycle. The two operations at any level are two circles that closed at the level below.

6.2 Two children per parent

A cycle at the level above has two crossed dimensions. The natural question is whether the two dimensions come from one closed cycle (its two diameters) or from two closed cycles (one diameter each).

One closed cycle cannot supply both axes of the level above. A single cycle's two diameters are orthogonal within the cycle, but the cycle at the level above has internal geometry that does not reduce to the product of one cycle's projections. The cycle's sixteen positions trace a ring in the plane of the two projections, not a product grid.

The next level is therefore built from two completed cycles, each handing up one of its two diameters. Each contributing cycle made a choice: each one carries one diameter and contains the other. The branching factor is binary in both directions. One child per parent axis going down. Two children combining into one parent going up.

The Pythagorean conservation derived in Section 5.2 is the formal witness of this binary structure. Two diameters, two quadratic terms in the conservation law. The structure of the conservation matches the structure of the projection.

6.3 Crossings are ordered

Two cycles cannot cross while both are still running. A cycle becomes an axis only at closure, so a still-running cycle is not yet an axis and cannot serve as a parent cycle's crossed dimension. Every crossing is therefore ordered. One cycle closes first and becomes the standing axis. The second cycle closes into the first; it arrives at the crossing as it reaches its own closure.

The two axes of a parent cycle are not equivalent. There is a first-closer (the standing axis) and a second-closer (the arriving axis). The tentative reading in the present account is that the transactional axis (space) is the standing axis and the generational axis (time) is the arriving axis. This identification is consistent with broader readings of space versus time in the account but is not independently demonstrated. Section 10 lists it among the open questions.

6.4 Which diameter propagates

A closed cycle has two diameters and projects only one upward. Which one is the structural question.

The cycle alone does not choose. There is no privileged direction within the cycle that distinguishes its two diameters before a crossing event. The choice is made at the crossing: the diameter that propagates upward is the one aligned with the partner cycle. A partner crossing at angle 0° propagates the transactional diameter. A partner crossing at angle 90° propagates the generational. The partner determines which diameter goes up.

This means a closed cycle alone cannot become an axis. It must be crossed by a partner. The crossing completes the closure-to-axis projection by selecting which diameter becomes the carried one. A single cycle is structurally insufficient to climb the recursion; the climb requires two cycles meeting.

6.5 Means becomes identity at the level above

The recursion has a consequence that runs through Persistence Dynamics. While a cycle is running, it is doing work as part of a larger cycle one level above. The cycle is *means*: its function is to contribute to the cycle that contains it. Once the cycle's own round closes, its residue (its accumulated state, its specific configuration) becomes part of what the larger cycle is made of. The cycle has become substrate.

The same operation that closed the cycle is what fed its residue upward as identity-substrate at the level above. Identity at any level is the accumulated closure-residue of cycles that completed at the level below. A young system has little closure-residue and is identity-thin. A mature system has substrate built up across many cycles of internal closure and is identity-thick.

The conversion is one-way at any given closure event. A running cycle is means; a closed cycle is identity-substrate. The transition happens at closure, which is also the projection event.

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7. What has to be in place

For the structure derived in Sections 2 through 6 to be observable in a particular system, five conditions have to hold at that system. Each is a prerequisite: what reality has to have built up to before the cycle becomes readable as a coherent process. Each rests on the prior.

Identity. There is something that coheres enough to be the subject of holding. Without it, hold has nothing to act on, and the cycle has no locus. A cell with a membrane. A team that knows who is in it. A manuscript with a working title.

Other. There is something beyond the self that the cycle can engage with. Without it, cross has nothing to reach toward, and the cycle has no exterior to meet. The cell has an environment. The team has a market. The manuscript has a reader.

Occurrence. Engagement is actually happening. The hold and cross operations are doing work, on real substrate, in real time. Without occurrence, the structure of a cycle is available but no cycle is running.

Closure. A round of the cycle completes in such a way that what comes out of it becomes the substrate for the next round. Without closure, the cycle runs once and stops, because nothing it produced is reusable.

Recursion. The closed cycle is one element of a larger cycle, and contains smaller cycles inside it. Without recursion, the closed cycle stands alone; it does not connect to scales above or below it, and Persistence Dynamics' predictions about cross-scale behaviour do not apply.

These five are not symmetric. They are constructive: each one rests on the prior. A system that lacks identity cannot have other, occurrence, closure, or recursion. A system that has identity and other but lacks occurrence has the structure of a cycle without a cycle running. A system that runs but does not close has occurrence without completion, which is the signature of work that never compounds. A system that closes but does not recurse has internal completeness without cross-scale coupling.

The diagnostic logic that follows is to find the lowest unmet prerequisite and address it first. Work at any higher level bounces if the substrate underneath is unstable.

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8. What Persistence Dynamics contributes

The structural derivations in Sections 2 through 7 establish what Persistence Dynamics is. This section states what it adds to existing work and what it makes available that was not previously available.

8.1 Three specific structural additions

Three formal claims in this account are not present in the lineages it builds on.

The first is the internal four-regime kinematics. The two operations and their bit-states force exactly four regimes. The Gray-code argument and the substrate-matching argument independently force one traversal order through them. These results are derivations, not pattern-matches against observed four-phase cycles in particular domains. The four phases that biology, organisational science, and project management have each observed within their own substrates have a single structural source. That source is specified here.

The second is the carried-contained projection mechanism. A closed cycle has two diameters. Closure projects one of them upward as an axis at the level above, while the other stays at the cycle's own level as internal radial state. The Pythagorean relationship $carried^2 + contained^2 = R^2$ holds across the projection. This account of how scale-crossing works mechanically is, to the author's knowledge, original to Persistence Dynamics. The two children per parent that the projection forces is the formal witness of this binary structure.

The third is the relational character of the projection itself. A closed cycle alone cannot select which of its two diameters becomes the carried one. The partner cycle that crosses it makes the selection: the diameter aligned with the partner is the diameter that propagates. Scale-crossing is therefore intrinsically relational. A single cycle is structurally insufficient to climb the recursion. The claim sits adjacent to relational accounts in quantum mechanics (Rovelli) and to the self-referential closure of autopoiesis. The specific structural mechanism, *the crossing selects which diameter propagates*, does not appear elsewhere in this form.

8.2 A shared vocabulary across domains

Beyond these formal additions, Persistence Dynamics offers a vocabulary that travels across domains while keeping its structural content intact.

The four regimes name the same dynamical events in any system that satisfies the prerequisites listed in Section 7. A clinician reading Conservation failure in a Phase III trial and an organisational designer reading Conservation failure in an institution after a leadership change are reading the same regime, with the same diagnostic implications about which class of intervention applies. The shared vocabulary is grounded in shared geometry. Persistence Dynamics distinguishes itself from accounts that claim cross-domain applicability without specifying the structural mechanism that supports it.

The literature on change, growth, innovation, and transformation has historically run on one track. The literature on regeneration, resilience, sustainability, and repair has run on another. They have used different vocabularies, published in different journals, and rarely cited each other. The four regimes give them shared terms. Growth and innovation map structurally to Potentiality and Construction. Regeneration and resilience map to Conservation. Both serve Encounter, which is the regime where the system's prior work meets reality. The two literatures were always describing the same cycle from different positions in it.

A similar barrier has stood between whole fields working on different material. Oncology and organisational design. Immunology and team dynamics. Developmental biology and product development. Each field has its own terminology, journals, and conferences, and findings within one field have largely stayed within it. With a shared geometry running under all of them, a finding in one field has a structural form that can be read in another. A characterisation of why immune Encounter fails in a cold tumour has the structural form of a characterisation of why outreach fails in a cold market. In both cases the receiver has not loaded Potentiality, and no Construction can force a meeting the receiver is not ready

for. The cross-field exchange this enables is the kind of cross-pollination Frans Johansson named the Medici effect: ideas that emerge at the intersections of fields and would not have appeared inside any one of them alone.

8.3 An account that carries empirical risk

Persistence Dynamics is set up to fail under specific empirical conditions. The closure equation $d^2 + d = 1$ depends on no material. A persisting system whose geometry diverges from the account this paper derives would disprove it. The cross-domain applicability of Persistence Dynamics is a structural claim available for falsification in any of the domains it touches.

The diagnostic logic compounds across uses. Each persisting system read through the four regimes adds resolution to the reading of every subsequent system. The cell, the trial, the relationship, the institution: each is another instance of the same geometry, and each sharpens the reading of the others. Persistence Dynamics develops through this loop. Application surfaces what is missing in the theory. The theory then sharpens, and the next application reaches further. Section 10 names the open seams the account currently carries. Encounter, the lab where Persistence Dynamics is in active development, treats those seams as the working agenda.

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9. Relation to existing accounts

Persistence Dynamics builds on and is distinct from several existing accounts of how systems persist. This section names the relationships.

9.1 Dissipative structures

Prigogine's mathematics of dissipative systems gives the thermodynamic conditions under which far-from-equilibrium structures can self-organise. The account derives the conditions for organisation but does not specify the internal kinematics: what such a structure does once it has self-organised, in what sequence, with what relationship between its parts. Persistence Dynamics is that internal kinematics. The two accounts are complementary. A system must qualify as a dissipative structure under Prigogine's conditions before Persistence Dynamics' cycle is observable in it.

9.2 Autopoiesis

Maturana and Varela's autopoiesis names the topological closure that distinguishes living systems from merely dissipative ones: a living system produces the components that produce it. Persistence Dynamics is consistent with autopoiesis and adds the specific cycle by which the production of production happens. Autopoiesis specifies that the cycle is self-referentially closed. Persistence Dynamics specifies the four-regime, Gray-code-ordered, ϕ-closed structure that the self-referential closure runs as.

9.3 Free-energy principle

Karl Friston's free-energy principle and active inference describe how biological systems minimise prediction error by maintaining internal models of their environment. The accounts share adjacent territory: both describe how persisting systems maintain themselves against environmental drift through cyclic engagement. The free-energy principle is more developed mathematically (variational inference, generative models, Markov blankets). Persistence Dynamics is more developed structurally (the four

regimes, the forced order, the binary recursion, the ϕ-closure). The two are not in competition; where they overlap, they describe the same phenomenon from different starting points.

9.4 Complex adaptive systems

The complex-adaptive-systems literature names properties of adaptive networks: emergence, edge-of-chaos dynamics, fitness landscapes, agent-based behaviour. Persistence Dynamics shares the substrate-independence claim but differs in formal commitments. Complex adaptive systems theory has produced powerful empirical observations and resisted a single formal core. Persistence Dynamics offers a specific formal core and accepts the consequence that not all complex adaptive systems satisfy its commitments. Systems that satisfy the closure equation persist with the Persistence Dynamics geometry. Systems that do not satisfy it may still be complex and adaptive, but they do not persist in the sense Persistence Dynamics requires.

9.5 Integrated information theory

Integrated information theory addresses what makes a system conscious by quantifying the irreducibility of the system's causal structure. Persistence Dynamics does not address consciousness. The point of contact, if there is one, is in the closure deficit ρ_closure: a system's irreducible causal structure may correlate with the cleanliness of its closure. This is filed as a hypothesis.

9.6 What Persistence Dynamics does not claim

Persistence Dynamics is an account of the internal geometry of dissipative-autopoietic systems. It is not a theory of consciousness, meaning, cosmology, or physics. Several places in the structure resonate with physics. The choice of carried diameter at the crossing has the shape of complementarity in quantum measurement, for instance. These resonances are structural shape only. They are not advanced as physical claims. The domain of Persistence Dynamics is the kinematics of persistence in any system where dissipative-autopoietic conditions are satisfied.

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10. Open questions

The account's open seams are part of its character. The following are the most consequential unresolved questions at time of writing.

10.1 Transitions are threshold-dependent

Between each regime sits a singularity: an irreversible commit-point where the cycle crosses a threshold from one regime into the next. There are four such singularities per cycle, one per regime boundary. Each is a capacitor-flavoured event with its own threshold-driven dynamics. Capacitors do not run on clocks. They run on thresholds, and the time a threshold takes to cross is determined by upstream supply conditions rather than by any intrinsic timescale within the framework.

An empirical residence time between two adjacent regimes therefore measures two distinct things. It measures the regime's own clocked duration (Construction's throughput, Encounter's reaction time, Conservation's correction time) plus the supply-dependent time the system spent loading the threshold-crossing at the boundary leaving that regime. The two contributions cannot be read off from an aggregate residence ratio. Strict scale-invariance arguments that ignore this distinction will fail

empirically, and have. The structural claim that survives is sharper: ϕ enters Persistence Dynamics at the level-crossing only, through the closure equation, and any prediction about ratios between regime residences requires the threshold-loading times to be measured separately from the regime durations.

This is a falsifiable empirical programme. Separating the threshold-loading time from the clocked regime duration at each of the four singularities is the experimental work the framework asks for next.

10.2 The dimensional decomposition of position

The geometry suggests that the four-regime position of a cycle should be readable from two coordinates at the level below: the two child cycles that supply the parent's two axes. A natural corollary is that exactly two coordinates from below should saturate the regime position.

This corollary was tested on a clinical biomarker dataset and was not supported in its strong form. Either the corollary is wrong, or the observable used in the test was too coarse to see the saturation. The corollary does not propagate to the other commitments of the account: the two-children-per-parent recursion is supported by separate structural arguments and by the Pythagorean conservation law. But the corollary itself remains filed as not-yet-supported.

10.3 Which substrate closes first

The recursion forces the two axes of a parent cycle to be ordered: one closes first as the standing axis, the second closes into it as the arriving axis. The tentative reading is that the transactional axis (space) is the standing axis and the generational axis (time) is the arriving axis. This identification is consistent with broader readings of space versus time in the account but is not independently demonstrated. The reverse identification cannot yet be ruled out.

10.4 Direct measurement of the 1/ϕ contraction

The closure equation forces 1/ϕ contraction at the level-crossing. This has been verified analytically as the unique positive root of $d^2 + d = 1$. No direct physical or biological measurement of a 1/ϕ step between adjacent levels has been performed and published as such. This is the next major empirical test the account would benefit from.

10.5 The dynamical crossing case

The crossing-chooses-which-diameter mechanism has been worked out for the static case, where the partner cycle is treated as a fixed second axis. The dynamical case, where the partner cycle is reaching its own closure while the focal cycle also runs, has not been fully characterised. The prediction is that diameter selection becomes time-dependent in this case: a cycle may present as transactional-up at one phase of its partner's traversal and as generational-up at another. This is a falsifiable claim.

10.6 The particle-wave structural resonance

Several places in the structure resonate with physics. The choice between carried-transactional and carried-generational at the crossing has the shape of the particle/wave choice. Quantum measurement has the shape of the choice event. Complementarity has the shape of the carried-versus-contained split. These are structural resonances. They are not advanced as physical claims. Contact with the actual physics, including Fourier conjugacy, the uncertainty relation, and the Born rule, would be required to promote any of them from suggestive shape to defensible claim.

11. Empirical signatures that would disconfirm

The structural form makes specific predictions that controlled measurement can disconfirm. Each prediction below is what closure forces. The third column says how the prediction could be disproved.

Measurement	Structural prediction	Disconfirmation
Closure ratio between nesting levels	$d = 1/\phi \approx 0.618$	Adjacent levels contract by a different scalar ratio, robustly across measurements.
Conservation across a projection	$carried^2 + contained^2 = R^2$ on a given orbit	Non-conservation across multiple level-crossings of the same orbit.
Regime transitions on the 2-cube	Exactly one bit flips per step	A four-regime transition off the 2-cube perimeter (would contradict the Gray-code uniqueness theorem).
Damping product γT for $L = 4$	≈ 1.924	Persistent deviation under controlled conditions on a known four-level cycle.

The framework's substrate-independence is at risk in every one of these measurements. The closure equation $d^2 + d = 1$ does not depend on what is running through it. A persisting system whose geometry diverges from this account, measured across the entries above, disproves it.

Real cycles, in real substrates, deviate from the structural form. The deviation is where the substrate-specific physics shows up. The structural form is the reference; it is not a claim that every observed cycle returns the canonical numbers without correction for the substrate it is running in.

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