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Structural Adequacy for Signalling

The Chrysene–Nucleic Acid Complex as a Hybrid Channel, Scaffold Succession, and the Continuity of Directed Pathways

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Abstract. The enclosure paper establishes a map from a nucleic-acid sequence to the configuration of the membrane enclosing it, setting the stage for how that configuration is read. This paper determines what a reader must be. It shows that a complete signalling architecture requires five elements, that the complex supplies all five entirely from the products of the integrated synthesis, and that together they define the full capacity of any reader.
The framework is naturally hybrid. Seven orders of magnitude separate the persistence of the orientational state from the window in which it is read, allowing a continuous field to carry the state adiabatically as a discrete word and reducing the dynamics to a clean piecewise-deterministic process with the word held fixed. The covalent backbone preserves this timescale separation against lateral diffusion by holding the anchors in strict sequence. The intrinsic ordering established in the enclosure paper is therefore directly load-bearing here as well.
The photon serves directly as the carrier. The chromophore is the vessel skeleton, the bridge is the phosphodiester tether, and the acceptor is the base that tether was formed to carry, making the relay entirely self-contained. Because the two anchor types differ by three backbone atoms, their transfer rates separate by a factor of 45 to 142, reporting the pair type directly as a rate. The arithmetic selects the long-lived triplet state for readout — a sharp structural condition that is directly testable by measurement. This mechanism cleanly resolves the pair type while remaining invariant to the presented face, independently confirming the division established in the enclosure paper.
Discrimination is achieved through the response itself: an in-plane transition dipole absorbs uniformly across presented faces, so the architecture functions directly as a state-discriminating detector. Each window reports the composition of a contiguous subword, and the window length — the optical scale divided by the helical pitch — converges on a single value through two independent routes: the phase filter and the steric width of a unit. Full sequence recovery is enabled by overlapping windows that share their differences: the fibre is exactly, and any local degeneracy remains strictly bounded by the window regardless of strand length.

Keywords: Chrysene Formalism; signalling architecture; hybrid dynamics; content addressing; scaffold succession; topological invariant; structural adequacy; hypothesis register; falsification register

1 Introduction

The enclosure paper establishes an injection from a nucleic-acid sequence to the configuration of the membrane that encloses it. The templating orientations of the units, carried into the surface and referred to the bilayer normal, distinguish every sequence from every other at two bits per anchor. That paper then declines to say that anything reads the configuration, and is explicit that injectivity is a condition on decoding rather than an instance of it.

The declination is the starting point here. A condition on decoding is worth having only if one can say what a decoder would have to be, whether the architecture could contain one, and what any decoder would be unable to do.

1.1 What this paper addresses

Three questions. What a signalling architecture requires, and whether the complex supplies it without addition. What any reader of that architecture could achieve, and what none could. And what survives when the architecture is replaced — since the structures this account is a precursor to are not made of chrysene, and a claim of continuity is a claim about inheritance across replacement.

The answers are, in order: five ingredients, all supplied; a reading protocol whose ambiguity is bounded by the stimulus and not by the sequence, and no closed loop; and an invariant that is inherited together with a mechanism that is not.

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1.2 Organization

Section 2 fixes status and notation and restricts the chemistry to phosphorus. Section 3 refuses eight readings before any construction. Section 4 states what is imported. Section 5 is the thesis.

Sections 6 to 8 build the framework: the hybrid reduction and the separation that licenses it; the window and the composition observable, with a correction to the obvious framing of addressing; and the two paths along the tether, with the substrate-independence theorem on which the deferral of chemistry rests. Section 9 derives lateral organization from the corpus's own geometry.

Sections 10 and 11 are succession: the aggregate as mould and as frame, with the invariants that are inherited and the three that are not. Section 12 solves the decoding problem exactly. Section 13 fixes the carrier and computes the readout. Section 14 states the continuity argument and labels its kind. Sections 15 onward are the registers, the precedence entry, the targets and the conclusion.

Recovered. The orientational state and its injection into the surface; the anchor set and its ordering by the strand; the footprint and stacking geometry of a unit in a leaflet. Imported unamended at Section 4.

Proved here. Structural adequacy (Theorem 5.4); the necessity of a hybrid framework and its reduction (Theorems 6.1, 6.2); content addressing and the window (Theorems 7.6, 7.5); substrate-independence (Theorem 8.5); the identifiability criterion and its kernel (Theorem 12.2); the directional asymmetry and the impossibility of a closed loop on the discrete state (Theorem 12.9, Corollary 12.10); succession as a directed morphism with named non-inheritances (Theorems 10.4, 10.6, 10.7).

Found. That aggregation, which removes the subject of the enclosure paper, improves the addressing resolution of this one (Corollary 9.4); and that the invariant on which addressing depends is the invariant succession preserves, so that a decoder built on the scaffold survives the scaffold (Corollary 10.5).

Computed here. The timescale table; the window length; the domain scale and line tension; the bandwidth ceiling; the enumeration of confusable words at stated window lengths. Appendix B.

Supposed. The carrier couples to the orientational state with a bounded affinity ratio; the aggregation branch of the enclosure paper's regime hypothesis, where Section 9 requires it; and the non-degeneracy of a replacement, where Section 10 requires it.

1.3 Organization

Section 2 fixes status and notation. Section 3 refuses eight readings before any construction. Section 4 states what is imported. Section 5 is the thesis: five ingredients, and the architecture supplies them. Sections 6 to 8 build the framework — the hybrid reduction, the addressing, the transduction — and Section 8 contains the substrate-independence theorem on which the deferral of chemistry rests. Section 9 derives lateral organization from the corpus's own geometry rather than importing it. Sections 10 and 11 are succession: the aggregate as mould and as frame. Section 12 is the decoding problem and the first capacity in this corpus that means what the word means elsewhere. Section 13 compares carriers on the four properties the framework uses. Section 14 states the continuity argument and labels its kind. Sections 15 to 18 are the registers, the precedence entry, the targets and the conclusion.

2 Status, nomenclature, scope

Convention 2.1 (Status labels)**.** [A] As in the coordinating paper. [A] finite or axiom-free; [D] derived under named hypotheses, registered in Appendix A; [C] imported, with the source named; [E] molecular reading, which enters no proof. Scholia carry no label and enter no proof.

Convention 2.2 (Chemistry deferred, and by what right)**.** [A] No statement of this paper depends on the identity of the carrier or on the chemistry of a successor. The deferral is not a modelling convenience and is not assumed: it is licensed by Theorem 8.5, which shows that every statement enters a carrier only through an affinity vector and a length scale. The licence is not unlimited. Section 13 is about the photonic carrier specifically and its statements do not transport; what transports is everything built on the response vector and the window, which is the whole of the framework and none of the chemistry. A reader who rejects Theorem 8.5 should read Sections 6 to 12 as conditional on a photon.

Notation 2.3 (Imported objects)**.** [C] From the enclosure paper: the anchor set $\mathcal{A}$ of a strand, ordered by the covalent backbone; the orientational datum at each anchor, a pair in $(\mathbb{Z}/2)^2$; the word w they compose; the footprint and stacking face of a unit in a leaflet. Restated, not reconciled by context.

Convention 2.4 (Scope)**.** [A] The object is one closed membrane carrying anchored units of one strand. Nothing is asserted of an assembly of membranes, of exchange between them, or of any process that divides one.

3 Non-implications

Proposition 3.1 (Non-implications of this paper)**.** [A] *None of the following is asserted anywhere below.*

(i) That any signalling pathway is exhibited. *What is exhibited is a set of conditions, a reading protocol, and a set of bounds. No process of the corpus is shown to perform the protocol.*

(ii) That the architecture signalled. *Possession of the ingredients is compatible with their never having been used, and Scholium 5.7 says so where the thesis is stated.*

(iii) That a chrysene unit becomes a sterol. *The transformation is named at Remark 9.6 with what it would require, is placed in deep time, and is used in no numbered statement.*

(iv) That divalent cations participate. *They are deferred with the sterol transformation at Remark 13.17, and by Convention 13.18 no metal enters any numbered statement.*

(v) That a catalytic or mechanical successor forms. *Succession is a morphism between structures; the existence of a successor is a premise of every statement that mentions one, and the chemistry of one is nowhere asserted.*

(vi) That a pore conducts. *Theorem 11.2 is topological. No conductance, selectivity or gating is computed, and a pore in that sense is a hole and not a channel.*

(vii) That morphogenesis, or any organism-level function, is reached. *By Corollary 12.10 the architecture supplies no closed loop, and a regulatory function requires one.*

(viii) That continuity is proved. *Section 14 gives a parsimony argument and labels it in the sentence that gives it.*

Scholium 3.2 (Why (v) and (viii) are stated together)**.** The two refusals guard one door from opposite sides. A succession framework that asserted its successors would be claiming a chemistry it has none of; a continuity argument that took itself for a proof would be claiming a history it has none of. Between them the paper holds something narrower and positive: that the ingredients are present without addition (Corollary 5.5), and that inheritance across a replacement is decidable rather than rhetorical (Theorem 10.6).

4 The reference architecture

This section fixes the objects the remainder of the paper works on. Its content is imported: every statement carries [C] or is a definition, and no result is derived here.

Proposition 4.1 (The anchored strand)**.** [C] *Import the anchored duplex in its membrane: anchors in strand order, each borne by a unit occupying one leaflet with its aromatic plane containing the normal, at the footprint and tilt range the enclosure paper computes.*

Proposition 4.2 (The orientational state)**.** [C] *Import the pair (α, β) at each anchor and the injection of the word into the surface configuration, together with the dichotomy on which its fibres are of size one or of size 2^m.*

Definition 4.3 (The persistent state space)**.** [D] Let $\mathcal{S}$ be the set of surface configurations reachable by the anchored units — the orientational word together with the slow geometric variables. Fix the timescale on which $\mathcal{S}$ is persistent at Table 1.

5 The five ingredients

The thesis of this paper is a claim about what exists rather than about what happens, and the claim is sharpened by fixing in advance what a signalling architecture requires. The definition below is stated before the architecture is examined, so that it cannot be shaped to fit it.

Definition 5.1 (Signalling architecture)**.** [D] A signalling architecture is a quintuple $(\mathcal{S}, \mathcal{R}, \mathcal{T}, \tau, E)$:

(a) $\mathcal{S}$, a state space persisting over the duration of a signal;

(b) $\mathcal{R}$, a response distinguishing the states of $\mathcal{S}$;

(c) $\mathcal{T}$, a path carrying a state to a variable elsewhere;

(d) τ, a separation under which $\mathcal{S}$ is quasi-static against the stimulus;

(e) E, an energy source external to $\mathcal{S}$.

Each clause has an independent failure mode. A reader who would add a sixth should add it here, where it can be tested, rather than object later that the list was convenient.

Remark 5.2 (What the definition deliberately omits)**.** [A] Three things a reader may expect are absent and their absence

is intended.

There is no requirement of a *decoder*: a state distinguishable in principle is the object of this definition, and whether anything distinguishes it is Target 18.9. There is no requirement of *feedback*, which Corollary 12.10 shows the architecture does not have. And there is no requirement of *function*: nothing in the definition asks that the signal do anything.

The definition is therefore weaker than a reader might want, and Scholium 5.7 says why a weak definition is the right instrument here.

Example 5.3 (An assembly that fails the definition)**.** [A] The definition is weak and a weak definition must be shown not to be vacuous. Consider the unrecruited dimers of the enclosure paper before scission: a pool of identical molecules in solution.

They fail clause (a): the pool has no per-molecule state to persist, every member being identical. They fail clause (b) for the same reason, a response having nothing to distinguish. They satisfy (c) vacuously, (d) trivially and (e) by any illumination. Two clauses of five fail, and they fail because the templating has not yet happened.

That is the content of the definition and it is what the thesis turns on: the same material before the encoding is not a signalling architecture and after it is. A reader who finds the five clauses too easily met should test them against this example before the complex.

Theorem 5.4 (Structural adequacy)**.** [D] *The chrysene–nucleic acid complex is a signalling architecture in the sense of Definition 5.1, and each ingredient is supplied by a feature the architecture possesses for an unrelated reason:*

(a) $\mathcal{S}$ *by the orientational state, which the templating fixed and the membrane preserves (Proposition 4.2);*

(b) $\mathcal{R}$ *by the difference in tether length between the two anchor types, read as a transfer rate (Theorem 13.5);*

(c) $\mathcal{T}$ *by the phosphodiester tether, which is a covalent path from the membrane to the sequence (Remark 8.1);*

(d) τ *by the seven orders separating the orientational lifetime from the readout window (Theorem 6.2);*

(e) E *by the photon, absorbed by the vessel skeleton itself (Proposition 13.1).*

Corollary 5.5 (Nothing is added)**.** [A] *No ingredient of Theorem 5.4 requires a component the integrated synthesis does not produce. The chromophore is the vessel skeleton, the bridge is the tether, the acceptor is the templated base, the state is the templating orientation, and the stimulus is external. No metal, no cofactor, no transporter and no oxidizing equivalent enters any clause.*

Table 1: Characteristic times. Transcribed from block V1; nothing here is asserted.

process	time (s)
photon absorption	10^{-15}
vibrational relaxation	10^{-12}
intersystem crossing to T_1	10^{-8}
arm rotamer transition	10^{-8}
electron transfer, T_{A} tether	2×10^{-7}
strand internal fluctuation	10^{-6}
electron transfer, T_{C} tether	2×10^{-5}
triplet decay, unquenched	10^{-3}
orientational reversal	10^{4}

Remark 5.6 (What would falsify the thesis)**.** [A] Two things, of different weights.

An ingredient shown *absent* refutes Theorem 5.4 outright: a state that does not persist, a response that does not discriminate, a path that does not carry. Each is a measurement.

An ingredient shown to be present only by a *later addition* leaves the theorem standing and refutes the continuity argument of Section 14. That is the more likely of the two and the one a reader should test first, since it is Corollary 5.5 and not Theorem 5.4 that the continuity claim rests on.

Scholium 5.7 (Adequacy is a weak claim, deliberately)**.** The status of the claim should be stated explicitly. That an architecture has the ingredients of a signalling system is compatible with the system never having signalled; the definition constrains structure and not history.

The claim is nonetheless worth establishing, for two reasons, neither of which is its strength. The alternative — that the ingredients were absent and were later supplied — is a substantive historical claim with a burden of its own, and Corollary 5.5 is what shifts that burden. And the bounds of Section 12 follow from the ingredients whether or not anything ever used them: the kernel of Corollary 12.3 and the impossibility of Corollary 12.10 are properties of the architecture and not of any history it had.

A thesis of modest strength with determinate consequences is of more use here than a stronger one without them.

6 Timescales, and why the framework is hybrid

Theorem 6.1 (The framework is necessarily hybrid)**.** [D] *No purely continuous model represents the orientational state, which takes two values at each anchor and does not interpolate; no purely discrete model represents the excitation and its transfer, whose kinetics are continuous and fast. The state of the system is therefore a pair: a word in a finite set, and a point in a continuum.*

Theorem 6.2 (Reduction, and the separation that licenses it)**.** [D] *The orientational word persists for* 10^{4} *s and the measurement window is the triplet lifetime at* 10^{-3} *s, a separation of seven orders. Over a readout the word is therefore a frozen parameter, the fast variables average, and the dynamics reduce on the slow manifold to a piecewise-deterministic Markov process with jumps at excitation and at transfer. The error is of the order of the ratio of the two times.*

Proof. The separation is finite given the table; Appendix B, block V1, computed. The reduction itself is standard and is imported rather than reproved: a system whose discrete component is frozen over the relaxation of its continuous one is a piecewise-deterministic Markov process in the sense of [Dav93], and the averaging of the fast component with an error of the order of the rate ratio is the standard result there. Nothing in this paper's setting requires an extension of it. □

Remark 6.3 (Why lateral diffusion does not enter)**.** [A] A reader checking Table 1 will look for lateral diffusion and find it absent, and the absence is a result rather than an oversight.
Free diffusion of a unit over an anchor spacing would take of order a microsecond, which is not slow against the readout and would spoil the reduction. It does not enter because the anchors are not free: they are held in order by the covalent backbone of the strand, so what fluctuates on that timescale is the strand's internal geometry and not the order or the identity of the anchors. The ordering established without premise in the enclosure paper is therefore load-bearing in a second and unrelated respect, which that paper had no occasion to examine.

Scholium 6.4 (The hybrid character is a property of the object)**.** It is worth insisting that the hybrid framework is forced and not chosen. An account that discretized the excitation would lose the averaging that makes the word a parameter; one that made the word continuous would be describing a different molecule. The seven orders of Theorem 6.2 are a fact about a triplet lifetime against a reorientation barrier, not about the modeller.

7 Addressing

Proposition 7.1 (Position addressing is unavailable)**.** [C] *Lateral diffusion destroys any map from a location in the membrane to a particular anchor; imported from the enclosure paper's refusal of the spatial reading.*

Remark 7.2 (A correction to the obvious framing)**.** [A] The natural way to describe an addressed architecture is that the stimulus *selects* a subset of the state space, and an earlier form of this paper was written that way. For the photonic carrier it is wrong, and the correction changes what the following theorems say.
A photon does not select by state. It is absorbed by whichever unit lies in the illuminated region, and the orientational state does not enter the absorption: the transition dipole lies in the molecular plane and an in-plane dipole is carried to its own negative by the flip that changes the presented face, so the two states absorb alike.
What discriminates is not the stimulus but the *response*. The states differ in what becomes of the excitation, by Theorem 13.5, and the architecture is therefore a state-discriminating detector rather than a state-selective filter. The distinction matters because a filter would return a subset and a detector returns a distribution, and the decoding problem of Section 12 is the second and not the first.

Definition 7.3 (Response vector)**.** [D] For a carrier s let k_s give the state-dependent response of a unit. For the photonic carrier of Section 13 it is the excited-state decay rate, which by Theorem 13.5 depends on the tether length and hence on the pair type. It is not constant, which is what makes the architecture readable at all.

Hypothesis 7.4 (Local extension)**.** [D] The strand is locally extended along the surface over the window: a region of the membrane of the stimulus length scale meets one stretch of the strand and not two. Registered as H7 in Appendix A.
The premise is not free. A coiled or looped strand would present a spatially contiguous region covering a sequence-discontiguous set, and the reconstruction of Section 12 would fail — the window sums would not be sums over consecutive symbols and the identity of Theorem 12.2 would not hold. The persistence length against the window is what

would settle it.

Theorem 7.5 (The window)**.** [D] *Assume Hypothesis 7.4. A stimulus localized to a region of the membrane illuminates the units within it. Because the anchors are held in order by the strand (Remark 6.3), those units are a contiguous stretch of the anchor sequence and not a scattered set. The readable subsets of $\mathcal{A}$ are therefore exactly the contiguous subwords, of a length ℓ fixed by the stimulus length scale against the anchor spacing.*

Theorem 7.6 (The observable is a composition)**.** [D] *Within a window the readout returns a distribution of decay rates and not an assignment of rates to positions, the units being unresolved from one another. By Theorem 13.14 the rate reports the pair type, so the observable of a window is the* number *of anchors of each type in it: the composition of the subword, and not its arrangement.*

Remark 7.7 (What the measurement actually is)**.** [A] Theorem 7.6 speaks of a composition and a count, and the measurement is neither directly. A window returns a decay curve which is a sum of exponentials, one component per anchor type, and the composition is the ratio of their amplitudes. Recovering component amplitudes from a multi-exponential decay is ill-conditioned, and the conditioning improves with the separation of the rates.
At the discrimination of Theorem 13.6, some hundreds, the extraction is routine. At the air-saturated discrimination of Theorem 13.10, about three, it is not: two exponentials differing by a factor of three are not reliably separable at any practical photon count. The two results therefore bear on one another and should be read together — Corollary 13.11 is not only a statement about when the architecture could read but about when the reading is extractable at all.

Corollary 7.8 (Resolution)**.** [A] *The window length is the stimulus length scale divided by the spacing of engaged anchors, and that spacing is the helical pitch of* 3.57 *nm, fixed by two independent arguments: the phase filter of the enclosure paper admits one anchor per turn, and a unit of* 0.74 *nm cannot stand* 0.34 *nm from its neighbour. Hence $\ell = 30$ for a diffraction-limited stimulus at* 300 *nm and $\ell = 6$ for a near-field one at* 20 *nm.*

Proof. Finite; Appendix B, block V2, computed at four stimulus scales. □

Remark 7.9 (What is favourable here and what is not)**.** [A] Two things, running opposite ways, and the paper is better for stating both.
Favourable: the architecture is readable at all, and it is readable because of features it has for other reasons. The two tethers differ in length, and the bases they carry differ in donor strength, and both differences were fixed by the templating long before anything read them. By Theorem 13.6 the two contributions are of the same order and reinforce, so the discrimination is larger than either would give; by Corollary 13.7 the paper cannot say which supplies it.
Unfavourable: the readout loses the arrangement within a window and keeps only the count. That is a real loss and it is the whole subject of Section 12, where it is shown to be bounded by ℓ rather than by the length of the strand.

8 Transduction, and substrate-independence

Remark 8.1 (Two paths along the same arm)**.** [A] The tether carries two kinds of transmission and the paper keeps them apart throughout.
The *electronic* path is fast. An excitation on the chromophore transfers to the base along the phosphodiester bridge at the rate of Theorem 13.5, without nuclear rearrangement. It is the path the photonic carrier uses, it is the readout of Section 13, and by Table 1 it runs in hundreds of nanoseconds.
The *conformational* path is slow. A change at one end reshapes the rotamer landscape and the population at the other end shifts, at the relaxation rate of Theorem 8.3. It is the path a mechanical stimulus would use and the path by which the sequence acts on the membrane.
The same nine atoms carry both, which is an economy of the architecture and is also why Remark 8.7 matters.

Definition 8.2 (The arm as a controlled chain)**.** [D] Model the tether arm as a finite Markov chain over rotamer configurations, with any slow stimulus entering as a control that reshapes the transition rates. The electronic path of Remark 8.1 does not enter this chain: it is a transition of the electronic state at fixed nuclear configuration, and its rate is a function of the configuration rather than a transition between configurations.

Theorem 8.3 (Propagation on the conformational path)**.** [D] *Transmission is the shift in the stationary distribution at one end induced by a change in the control at the other. The transmitted quantity is a population shift and not a*

displacement, and the rate at which it establishes is bounded by the spectral gap of the uncontrolled chain.

Corollary 8.4 (The two paths do not compete)**.** [D] *By Table 1 the electronic transfer and the rotamer transition are of the same order, so an excitation is transferred before the arm has relaxed and the readout samples the configuration the arm was in. The readout therefore reports a static distribution over configurations rather than a dynamic average over them.*

Theorem 8.5 (Substrate-independence)**.** [D] *Every statement of Sections 6 to 12 enters the carrier only through the response vector k_s of Definition 7.3 and the window length ℓ of Theorem 7.5. Hence any carrier whose response distinguishes the orientational states with a bounded ratio, and whose stimulus has a length scale, yields the same framework with rescaled constants: the hybrid reduction, the window, the composition observable, the exact fibre of Theorem 12.2 and the bound of Corollary 12.3 are unchanged.*

Proof. By inspection, statement by statement. Each line names what the statement uses of the carrier.

- Thm. 6.1: that the state is discrete and the carrier field continuous. Uses neither k_s nor ℓ, and no property of the carrier beyond its being a field.
- Thm. 6.2: the separation of Table 1. Uses the carrier's relaxation time only through the requirement that it be fast against the state.
- Prop. 7.1: imported; uses no carrier.
- Thm. 7.5: the stimulus length scale, which is ℓ.
- Thm. 7.6: that the response is unresolved within a window and depends on state through k_s.
- Thm. 8.3: the spectral gap of the arm, a property of the arm and not of the carrier.
- Thm. 12.2 and Cor. 12.3: the window sums alone. Combinatorial; no carrier enters.
- Thm. 12.5: k_s through the noise model, ℓ through the fibre.
- Thm. 12.9 and Cor. 12.10: the ordering of Table 1, and the requirement that the inward carrier not act on the orientational state directly.

No statement uses a further property. The exceptions are Theorems 13.5, 13.6 and 13.9 and Corollaries 13.7 and 13.11, which are about the photonic carrier specifically, are confined to Section 13, and are what supply the values of k_s that the statements above take as given. □

Scholium 8.6 (What the theorem licenses, and what it does not)**.** This is the theorem that permits Convention 2.2, and its scope should be stated exactly.
It licenses the deferral of chemistry: no result below depends on the carrier being a photon, and a later architecture reading the same states by some other means would obtain the same bounds. It does not license indifference to chemistry. Which carrier is available decides whether k_s distinguishes anything at all, and Section 13 finds exactly one carrier that does so without requiring a development the architecture has not had. The framework is carrier-independent; the architecture's possession of a carrier is not.

Remark 8.7 (The read perturbs the readable)**.** [A] A carrier coupling to the arm modulates the rotamer population on which the enclosure paper's conformational premises stand — the folding that keeps a unit within one leaflet, and the freedom that lets it present either face. Reading the membrane therefore perturbs the condition under which the membrane is readable.

For the photonic carrier the perturbation is bounded and the bound should be named: an excitation deposits a few electron volts, which is large against $k_B T$, but it is deposited in the electronic system and returns to the ground state within the triplet lifetime, and the number of excitations per unit per readout is under the experimenter's control. Register the hypothesis as the statement that the time-averaged perturbation over a readout leaves both premises standing, and name the ratio that measures it.

9 Lateral organization

Proposition 9.1 (The contact a unit offers)**.** [A] *A unit occupies* 0.39 *to* 0.43 nm^2 *of the plane and presents a lateral face of* $1.25 \times 0.70 = 0.88$ nm^2*, which is about twice its footprint. By the orientation imported at Notation 2.3 the face stands with the membrane normal in its plane, so it is available to a neighbour without any reorientation.*

Proof. Finite; Appendix B, block V3, computed. □

Theorem 9.2 (Domains, and the line tension in a named parameter)**.** [D] *Under the aggregation branch, units segregate into domains. Let ε be the free energy of lateral contact per unit area of stacking face. A unit in the interior of a domain satisfies its face on both sides; a unit at the edge satisfies it on one. By Proposition 9.1 the face is* 0.88 nm^2 *and a unit presents* 0.74 *nm of edge, so the line tension is*

$$\gamma = \tfrac{1}{2}\,\varepsilon\,\frac{0.88}{0.74} = 0.59\,\varepsilon \text{ nm},$$

and a domain of N units has an edge cost $\gamma \cdot 2\sqrt{\pi N a}$ with a the footprint, against a bulk gain linear in N.

Remark 9.3 (Why the scale is not emitted)**.** [A] The domain scale follows from γ against the entropy of mixing and is therefore a function of ε alone, every other quantity in the expression being computed. This paper does not supply ε: a free energy of aromatic contact in an acyl core is not obtainable from the geometry the corpus prints, and estimating it from gas-phase stacking energies would import a number from the wrong environment — which is the error Theorem 13.10 identifies in the triplet lifetime and which should not be repeated here.
What is established is the form of the dependence and the two lengths entering it. The value is Target 18.7, and until it is supplied the aggregation branch is a regime with a known criterion and an unknown scale.

Corollary 9.4 (Aggregation raises the resolution)**.** [D] *Within a domain the relative positions of units are fixed, so the window of Theorem 7.5 is a fixed set of sites rather than a moving one, and the readable subwords refine accordingly. The branch that removes the subject of the enclosure paper therefore improves the channel of this one.*

Remark 9.5 (An inversion, and what the corpus should do with it)**.** [A] The enclosure paper assumes dispersal and records that aggregation would replace its subject rather than weaken its statements. This paper finds the opposite sign: aggregation is what makes the assembly readable with precision, because a window over fixed sites reports a fixed subword and a window over diffusing ones does not.
The two papers therefore want opposite values of one hypothesis. That is a fact about the corpus and not about either paper, and it should be recorded where coordination findings are recorded rather than left for each paper to assume what suits it. Settling the regime will cost one of the two accounts something, and the trade-off should be recorded rather than left implicit in either.
Two remarks bound the damage. The enclosure paper's finite content — the scission, the ledger, the geometry — is independent of the regime, so what aggregation costs there is Sections 8 and 9 of that paper and not the whole. And this paper's results survive dispersal in weakened form: the window is then a statistical rather than a fixed set, the composition observable is an expectation rather than a count, and Corollary 12.3 holds with the fibre replaced by a confidence set.

Remark 9.6 (The sterol correspondence, at deep time)**.** [E] Organized domains in extant membranes are sterol-organized, and the correspondence with Theorem 9.2 is noted and not argued from.
A transformation of a chrysene unit into a sterol would require a ring contraction, an addition of nine carbons, an exhaustive reduction and the installation of eight stereocentres. It is a deep-time hypothesis, presupposing an oxidizing environment and an enzymatic network already in place, and it is not a step this architecture performs.
The oxidizing environment it presupposes is the one Corollary 13.11 shows disables the photonic readout. The sterol becomes reachable at about the point this paper's channel closes, and Remark 13.12 states what follows.
What the present section supplies is the prior organization such a transformation would inherit, which is the subject of Section 10. On that reading the sterol domain is a successor in the sense of Definition 10.2, and Theorem 10.6(a) then says something the correspondence alone would not: a sterol has two distinguishable faces only if its environment distin-

guishes them, so whether the orientational word survives that succession is a question with an answer rather than a matter of resemblance.

10 Succession: the aggregate as scaffold

The structures this account is a precursor to are not made of chrysene. A claim that a pathway present at the onset is the pathway present later is therefore a claim about inheritance across replacement, and it is empty unless replacement is given a mathematical meaning and unless some inheritances are shown to fail. This section supplies both.

Definition 10.1 (Assembly, and its invariant)**.** 🄳 An assembly is a finite set of sites, an adjacency relation on them, an orientation in $(\mathbb{Z}/2)^2$ at each site, and a group acting on the whole by permutations preserving adjacency. Let

$$\mathrm{Inv}(X) = \big(\text{adjacency type},\ \text{orientation pattern},\ \text{symmetry type}\big)$$

be the functor recording those three and nothing else — in particular not the occupants of the sites, nor their conformational freedoms, nor their chemistry.

Definition 10.2 (Succession)**.** 🄳 A succession $X \to \mathcal{Y}$ is a map of sites that preserves adjacency and carries the orientation at each site to an orientation at its image. Write Asm for the category of assemblies with successions as morphisms. The occupant of a site in $\mathcal{Y}$ is unconstrained: what is inherited is the arrangement and not the material.

Hypothesis 10.3 (Non-degeneracy)**.** 🄳 A succession is injective on sites. A degenerate succession collapses the adjacency and carries no invariant; such maps are excluded here and are not shown to be rare.

Theorem 10.4 (Succession preserves the readable invariant)**.** 🄳 *Assume Hypothesis 10.3. The window of Theorem 7.5 and the composition observable of Theorem 7.6 depend on the assembly only through the adjacency and the orientation pattern, that is only through* Inv*. Hence a successor inheriting* Inv *presents the same readable structure, and the reconstruction of Theorem 12.2 applies to it unchanged.*

Corollary 10.5 (A decoder survives its scaffold)**.** 🄳 *A reading protocol constructed on the addressing of Section 7 continues to decode after a succession, with the response vector rescaled by Theorem 8.5 and nothing else amended. This is the formal content of the claim that a pathway present at the onset is the pathway present later.*

Theorem 10.6 (What is not inherited)**.** 🄳 *Three properties of a scaffold are provably not carried by an arbitrary succession, and naming them is what keeps the framework from permitting everything.*

(a) The orientation pattern, unless the successor is two-sided. *An orientation in $(\mathbb{Z}/2)^2$ requires an occupant with two distinguishable faces. A succession to an occupant with none carries no second component, the pattern collapses to its first, and the word available to a reader falls from two bits per site to one.*

(b) Chirality, unless the successor is chiral. *The handedness the residue account transfers from the sugar to the residue is a property of an occupant and not of an arrangement. It is absent from* Inv *and is lost at a succession to an achiral occupant.*

(c) The scaffold's own conformational freedoms. *The rotamer states of the arms, on which the readout of Section 13 and the premises of the enclosure paper both stand, have no image in* Inv *at all.*

Theorem 10.7 (Succession is one-way)**.** 🄳 *A succession has no inverse in* Asm*. By Theorem 10.6(c) the scaffold's conformational freedoms are not determined by the successor, so no morphism recovers them; and* Inv *is preserved and not created, so no morphism supplies an invariant the source lacked. The category is therefore directed, and a chain of successions is a chain and not a cycle.*

Scholium 10.8 (What the directedness buys)**.** Without Theorem 10.7, the claim that signalling was in place at the onset admits no refutation: any structure may be said in retrospect to have inherited its organization from a predecessor.

With it the claim acquires a shape. No succession creates Inv and none restores what a succession removes, so the invariant that makes a later structure readable is one a predecessor must have carried. That is a constraint on histories rather than a history, and a reader may attack the constraint — by exhibiting a route that creates an invariant, which would refute the theorem, or by denying that the later structure carries the invariant at all, which would make the question moot.

It is worth adding what the theorem costs the account. A directed category has no reversibility, so nothing in this framework permits a structure to recover a freedom it has

given up. An architecture that replaced its scaffold has replaced it, and the conformational readout of Section 13 — which is this paper's only exhibited readout — is precisely what Theorem 10.6(c) says does not survive. The pathway is inherited; the particular mechanism this paper computes is not.

Example 10.9 (A succession worked through)**.** [D] The functor is proved over and would otherwise be exhibited nowhere. One instance, hypothetical in its chemistry and exact in its bookkeeping.
The scaffold. Six units in a closed ring, by Corollary 11.3: sites $1, \dots, 6$ with adjacency the cycle C_6, an orientation in $(\mathbb{Z}/2)^2$ at each, and symmetry group the cyclic group of order six. So Inv = (C_6, the six orientations, $\mathbb{Z}/6$).
The succession. Replace each unit by a residue borne at the same site, the residues joined between adjacent sites. The map on sites is the identity, so it is injective and Hypothesis 10.3 holds.
Carried. The adjacency C_6, since the residues are joined where the units were adjacent. The symmetry $\mathbb{Z}/6$, since the arrangement is unchanged. The genus of the complement, so the aperture survives as an aperture of the same size by Corollary 11.6.
Lost, and demonstrably. The orientation pattern, unless a residue has two distinguishable faces — most do not, and by Theorem 10.6(a) the word then collapses from two bits per site to one. The rotamer states of the arms, which have no image in Inv at all, and with them the readout of Section 13: the successor is addressable in the sense of Theorem 10.4 and is not readable by the mechanism this paper computes.
What the example shows. That the functor separates: it carries three things and drops two, and the two it drops include the one the paper's own channel runs on. A framework in which nothing was lost would not have needed Theorem 10.6.

Remark 10.10 (The catalytic realization)**.** [E] One realization of a succession is a mould. An aggregate whose sites are occupied by units coordinated with residues fixes an arrangement; a catalytic successor formed in the complement — by bond formation between residues held at adjacent sites — would occupy that arrangement and inherit its adjacency. The chemistry is not this paper's and is asserted nowhere. What the paper supplies is the invariant such a successor would carry, the sense in which it would remain readable (Theorem 10.4), and the geometric condition on which the realization depends at all (Target 10.11).

Target 10.11. Determine whether residues held at adjacent sites of an aggregate are within bond-forming distance and orientation. By block V3 the sites are of order 0.7 nm apart, which is the right order for a bond between groups borne on arms, and the question is whether the arms can present them. It is geometric, is finite once the aggregate spacing and the residue geometry are written down, and decides whether the catalytic realization is available at all.

11 Mechanical realizations: frame, pore, rotor

A second class of successor is mechanical rather than catalytic, and its invariant is topological rather than combinatorial. The section is short and its statements are about genus and symmetry. Nothing here is about force.

Definition 11.1 (The frame of an aggregate)**.** [D] The frame of an aggregate in a membrane is the pair: the genus of the complement of the aggregate within a patch of the surface, and the symmetry type of its site arrangement. Both are components of Inv.

Theorem 11.2 (A closed cycle is a pore)**.** [A] *An aggregate whose adjacency graph contains a cycle bounding a disc in the patch has a complement of genus one there, and the bounded component of that complement is an aperture. A ring of n units of width d in mutual contact has ring radius $d/2\sin(\pi/n)$ and aperture radius $d/2\sin(\pi/n) - d/2$.*

Proof. Finite; Appendix B, block V4, computed at seven ring sizes. □

Corollary 11.3 (The apertures the geometry admits)**.** [A] *At the unit width of* 0.70 *nm imported at Notation 2.3, the smallest closed ring is six units and admits an aperture of* 0.70 *nm; eight units admit* 1.13 *nm and twelve admit* 2.00 *nm. The aperture is lined by the phosphodiester arms of the units that bound it.*

Remark 11.4 (What the numbers are and are not)**.** [A] These are the dimensions of an ion channel rather than of a transporter, and the lining is anionic. The correspondence is recorded and is used nowhere: this paper computes no conductance, no selectivity and no gating, and a pore in the sense of Theorem 11.2 is a hole and not a channel.
What the correspondence does bear on is Remark 13.17. A later architecture acquiring the coordination chemistry

that paper defers would find a frame of the right dimensions already standing, and would not have to build one. That is a statement about what is inherited, not about what occurs, and it is exactly the kind of statement Section 10 exists to make.

Theorem 11.5 (Cyclic symmetry and rotation)**.** [D] *An aggregate whose site arrangement carries a cyclic symmetry of order n admits a rotation of order n about the membrane normal preserving adjacency and permuting the sites cyclically. Since* Inv *is preserved, the orientation pattern is carried around the cycle, and the readable subwords of Theorem 7.5 are permuted cyclically with it.*

Corollary 11.6 (The mechanical invariants are succession-stable)**.** [D] *Genus and symmetry type are components of* Inv*, so by Theorem 10.4 a pore survives a succession as a pore of the same genus and a rotor as a rotor of the same order. An occupant of a chrysene-defined aperture inherits the aperture.*

Remark 11.7 (What is not claimed mechanically)**.** [A] No force, no torque, no throughput, no gating and no directionality of rotation. A rotor in the sense of Theorem 11.5 is a symmetry, not a motor: nothing here supplies the asymmetry a motor requires, and by Corollary 12.10 nothing here supplies the feedback a controlled one would.

12 Decoding: identifiability, the kernel, and capacity

Opening: the enclosure paper established an injection and exhibited no decoder. This section exhibits the decoding problem the photonic readout poses, solves it exactly, and computes what it costs.

Definition 12.1 (The channel)**.** [D] A stimulus programme u is a sequence of window positions. The state is the pair-type word $w \in \{a, c\}^m$, by Theorem 13.14. The observable y is, for each window, the composition of that window, by Theorem 7.6. Noise enters through the counting statistics of the decay and through the finite contrast of Theorem 13.5.

Theorem 12.2 (Identifiability, and the exact fibre)**.** [D] *Let the windows be the $m - \ell + 1$ contiguous subwords of length ℓ, and write S_i for the composition of the ith. Then*

$$S_{i+1} - S_i = w_{i+\ell} - w_i,$$

so the word is determined by its first ℓ symbols together with the observed differences. The words consistent with an observation are exactly those whose first ℓ symbols sum to S_1, and the fibre has size

$$\binom{\ell}{S_1}, \qquad \max_{S_1} \binom{\ell}{S_1} = \binom{\ell}{\lfloor \ell/2 \rfloor}.$$

Proof. The displayed identity is immediate from the definition of S_i. It determines $w_{i+\ell}$ from w_i for every i, so a choice of the first ℓ symbols determines the word; and a choice is consistent if and only if it meets S_1. Appendix B, block V5, computed, with the closed form checked against exhaustive enumeration at nine combinations of m and ℓ. □

Corollary 12.3 (The kernel is bounded by the window, not by the strand)**.** [A] *The information lost is at most $\log_2 \binom{\ell}{\lfloor \ell/2 \rfloor}$ bits, which depends on ℓ and not on m. At the window lengths the optics deliver — $\ell = 30$ diffraction-limited and $\ell = 6$ near-field, by Corollary 7.8 — the loss is 27 bits and 4 bits respectively, and it is the same loss whether the strand carries a hundred anchors or a thousand.*
The first figure is a quarter of a hundred-anchor word and a fortieth of a thousand-anchor one. Against a one-bit-per-anchor channel the diffraction-limited readout is therefore useful for long strands and poor for short, and the near-field readout for both.

Scholium 12.4 (Why the bound is the section's result)**.** A channel whose kernel grew with the length of its message would be useless for any message worth sending: the fraction recovered would fall toward nothing and the architecture would read short sequences and no others.
What Corollary 12.3 establishes is that this channel is not of that kind. The loss is a fixed cost, paid once at the head of the word, and it is the price of the window rather than a rate of decay along the strand. The reason is structural and worth naming: the windows overlap, and overlapping windows share their differences. A readout by disjoint windows would lose the arrangement within every one of them and the kernel would indeed grow; it is the sliding that recovers the word, and the sliding is available because the anchors hold their order.

Theorem 12.5 (Capacity, and its finite-photon behaviour)**.** [D] *In the noiseless limit the mutual information $I(w; y \mid u)$ is $m - \log_2 \binom{\ell}{S_1}$ bits, by Theorem 12.2.*
At finite photon number the window observable is an estimate of a composition rather than a composition, by

Remark 7.7. Writing N for the photons collected per window and $r = \tau_C/\tau_A$ for the contrast of Theorem 13.10, the Fisher information of the amplitude ratio scales as

$$I_F \propto N\,\frac{(r-1)^2}{(r+1)^2},$$

so the standard error of a composition falls as $N^{-1/2}$ and rises steeply as $r \to 1$. A window is resolved when that error is below half a unit of composition; below that threshold the fibre of Theorem 12.2 is replaced by a confidence set and the capacity falls continuously from the noiseless value toward zero.

Corollary 12.6 (Where the two failures meet)**.** [D] *The photon requirement and the era constraint are not independent. At the anoxic contrast $r \approx 79$ the factor $(r-1)^2/(r+1)^2$ is* 0.95 *and the estimation is photon-limited only; at the air-saturated contrast $r \approx 3.2$ it is* 0.27*, so some four times the photons are needed for the same composition error, on a triplet whose shorter lifetime also permits fewer excitations per unit time.*
Oxygen therefore degrades the readout twice over — through the contrast and through the budget — and Corollary 13.11 is the stronger for it.

Remark 12.7 (What this is, against the enclosure paper's quantity)**.** [A] The enclosure paper defined *capacity* as the entropy of an injection and said explicitly that it presumed no decoder. This section has an input, an output, a noise model and a decoding rule, so the word here carries its ordinary meaning. The difference should be stated where a reader of both will look for it: that paper established that the sequence is distinguishable in the surface; this one exhibits a procedure that distinguishes it, and prices the procedure. What is not thereby established is that anything in the architecture performs the procedure. The decoder of this section is a reading protocol, not a mechanism, and Target 18.9 remains as it was.

Theorem 12.8 (Bandwidth ceiling)**.** [A] *A window cannot be read faster than the triplet decays, so the readout rate is bounded by 10^3 windows per second, and a strand of m anchors read through $m - \ell + 1$ windows takes at least $(m - \ell + 1) \times 10^{-3}$ s. Block V6.*

Theorem 12.9 (Directional asymmetry)**.** [D] *The inward channel reads a discrete quasi-static state through the electronic path of Remark 8.1. The outward channel — from the sequence to the membrane — acts through the conformational path, and by Table 1 it can write the tilt and the position of a unit but not its orientational state, reorientation being seven orders slower than any process available to it. The asymmetry is in kind and not in rate.*

Corollary 12.10 (No loop closes on the discrete state)**.** [D] *Hence no feedback loop closes on the orientational word within the lifetime of an assembly. The membrane state is read-mostly from the sequence's side: a memory with a slow erase.*

Scholium 12.11 (The paper's sharpest negative)**.** Corollary 12.10 is the result that should persuade a sceptical reader, and not Theorem 5.4. Adequacy arguments are permissive by construction. A framework that excludes a closed loop on its own state variable admits a negative result, and a framework that admits negative results is one whose positive statements carry correspondingly more information.
It also bounds what the architecture could be a precursor of. A regulatory circuit requires a loop; this architecture supplies a read path and a slow write path that do not meet. What it is a precursor of, on the present account, is a readable memory and not a controller.

13 The carrier, and the readout it supplies

This is not a chemistry section. By Theorem 8.5 the framework uses a carrier through two properties only — an affinity vector and a length scale — and one carrier is available to the architecture at the onset without any development of it. This section fixes that carrier, computes the observable it yields, and says which bit the observable resolves.

13.1 Photoexcitation, and why it needs no development

Proposition 13.1 (The chromophore is present from the onset)**.** [C] *The chrysene skeleton is an aromatic chromophore absorbing in the near ultraviolet and carrying an accessible triplet. It is the same skeleton the encoding is written on and the same one the membrane is cut from: nothing is added to obtain it, and no transformation of the substituted unit is required before it absorbs.*

Remark 13.2 (Why this matters for the continuity argument)**.** [A] Every other carrier the corpus might reach for

requires something the architecture does not yet have — a coordination site, a cofactor, a transporter, an oxidizing environment. Photoexcitation requires nothing. The stimulus is external, the absorber is the structural unit itself, and the energy arrives without a gradient, a pump or a partner.
That is what makes the photonic channel the one to state first. A signalling channel available at the onset is a different kind of claim from one available after a development, and Section 14 rests on the difference.

13.2 The readout: a quencher supplied by the templating

Definition 13.3 (The photophysical observable)**.** [D] Let the observable y be the excited-state lifetime of a unit following excitation. Its decay is the sum of the intrinsic rate and the rate of any transfer to a proximal acceptor.

Proposition 13.4 (The nucleobase is the acceptor)**.** [E] *A nucleobase quenches an aromatic excited state by photoinduced electron transfer; an alkyl cap does not. The architecture therefore supplies donor, bridge and acceptor from three parts it has for other reasons: the chromophore is the vessel skeleton, the bridge is the phosphodiester tether, and the acceptor is the base that tether was formed to carry.*

Theorem 13.5 (The tether length is read as a rate)**.** [D] *Through-bond transfer attenuates as* $\exp(-\beta R)$ *with* R *the donor–acceptor separation. The two tethers differ by three backbone atoms,* 3.81 Å*, so their transfer rates differ by* $\exp(\beta\,\Delta R)$*: a factor of* 45 *to* 142 *over* $\beta = 1.0$ *to* 1.3 Å^{-1}*. Block W1.*

Theorem 13.6 (The base-dependent term is of the same order)**.** [D] *The two anchors differ in two respects at once: the adenine anchor carries the shorter bridge and a purine, the cytosine anchor the longer bridge and a pyrimidine. Purines are the better electron donors, adenine being easier to oxidize than cytosine by of order* 0.2 *eV.*
Taking a quarter to a half of that difference into the activation barrier gives a chemical factor of 7 *to* 49*, against the geometric factor of* 80 *at* $\beta = 1.15$*. The two are of the same order and they run in the same direction.*

Proof. Finite, given the potentials; Appendix B, block W4, computed over a range of driving-force differences and barrier shares. □

Corollary 13.7 (The discrimination survives; the attribution does not)**.** [D] *Because the two terms reinforce, the observed discrimination is the product, of order* 500 *to* 4000*, and is larger than either alone. The readout is therefore better than Theorem 13.5 alone would make it.*
What is not available is the attribution. The discrimination cannot be said to be a by-product of the templating geometry, a comparable part of it being a by-product of base identity.

Remark 13.8 (A claim withdrawn, and the test that would restore it)**.** [A] An earlier form of this section made a point of the geometric reading: a structure designed to be read could hardly have done better than to place a three-atom difference in a bridge whose attenuation is exponential. The claim is withdrawn at Remark D.3: it is not supported by the evidence now assembled.
What replaces it is weaker and remains of use. The architecture supplies a discrimination; two of its own features contribute to that discrimination; and which contributes more is a question with an experimental answer that requires no architecture at all. Compare one base at the two bridge lengths, or the two bases at one length: either separates the terms, on a model compound, by ordinary photophysics. Until that is done the paper claims a readout and not an explanation of it.

Theorem 13.9 (The readout requires the triplet)**.** [D] *On a singlet of ten nanoseconds the transfer rate at these separations is at or below the intrinsic decay rate, and the lifetime moves by between nought and thirty per cent — the states are not resolved. On a triplet of a millisecond the intrinsic rate is five orders lower, every transfer channel dominates it, and the lifetimes separate by between two and four orders.*
The readout therefore requires the long-lived triplet and not the singlet. This is a derived structural requirement: a chromophore with no accessible triplet could not be read this way at all. Block W2.

Theorem 13.10 (The readout requires an anoxic setting)**.** [D] *The triplet lifetime of Theorem 13.9 is a rigid, deoxygenated figure. Molecular oxygen partitions into an acyl core at three to five times its aqueous concentration and quenches an aromatic triplet at near the diffusion limit, so the operative lifetime is set by the oxygen content of the setting and not by the chromophore.*
Over that parameter the discrimination τ_A/τ_C *falls from* 79 *in an anoxic core to* 3.2 *in an air-saturated one, and the unquenched reference* τ_T/τ_A *from* 4542 *to* 3.3*. The discrimination exceeds tenfold only below about* 200 μM *in*

the core.

> *Proof.* Finite, given the quenching constant; Appendix B, block W2, computed at six concentrations. □

Corollary 13.11 (A constraint on the era)**.** [D] *The photonic readout is available in an anoxic setting and not in an oxygenated one. It is therefore not merely compatible with an early Earth: it requires one, and would be disabled by atmospheric oxygenation.*

Remark 13.12 (The two eras, and what each permits)**.** [A] The corpus now has an oxygen parameter appearing twice and pointing in opposite directions, and the relation between the two should be stated explicitly.
An anoxic setting permits this readout and forbids the sterol transformation of Remark 9.6, which needs an oxidizing environment. An oxygenated setting permits the sterol and disables the readout. The architecture described here can therefore read its own membrane at the onset and cannot do so after the atmosphere changes, while the structures it is a precursor to become reachable at exactly the point the precursor's own channel closes.
Nothing here establishes that anything used the channel while it was open, and Target 18.9 stands. What is established is that the window in which it could have been used is bounded above, and bounded by a date rather than by a premise.

Scholium 13.13 (A requirement, not a convenience)**.** Theorem 13.9 has three properties that recommend it as a test of the account. It was not sought but follows from the arithmetic; it is falsifiable by a photophysical measurement; and it constrains the architecture rather than accommodating it. A framework that could have used either state would have been telling us less.
Theorem 13.10 is of the same kind and is the sharper of the two. It converts a photophysical parameter into a statement about when the architecture could read, and it does so in a direction that costs the account something: the readout is not available at all times, and the times at which it is available are the early ones.

13.3 Which bit the channel resolves

Theorem 13.14 (The pair type is resolved; the presented face is not)**.** [D] *The donor–acceptor separation along the tether is fixed by the bond count and is the same whichever face a unit presents. Hence the lifetime resolves α, the pair type, at the contrast of Theorem 13.5, and does not resolve β, the presented face: the base stands at the same through-bond distance either way. Block W3.*

Corollary 13.15 (The division is reproduced physically)**.** [D] *The enclosure paper found the pair type carried unconditionally and the presented face carried only under a conformational premise. The photonic channel reproduces that division for an independent reason — a bond count against a depth — and not by inheriting the premise. Two accounts of the same asymmetry, from different grounds, are worth more than one.*

Target 13.16. Exhibit an observable sensitive to the depth of the base relative to the outer interface rather than to its bond count, which would resolve β and complete the channel. None is selected here, and until one is the photonic channel carries one bit per anchor.

13.4 What is deferred, and to when

Remark 13.17 (Divalent cations belong to a later era)**.** [E] A cation–π readout would place a divalent ion against an aromatic face in a membrane saturated with phosphodiester head groups, and would require coordination chemistry the architecture does not supply. It is deferred with the sterol transformation of Remark 9.6 and for the same reason: both presuppose a network already in place.
The deferral is not a dismissal. The pore geometry of Theorem 11.2 and the electrostatics of a phosphodiester-lined aperture are consistent with ionic transport, and a later architecture that acquired coordination chemistry would find the frame already built. What is claimed is only that none of this is required for, or available to, the signalling of the onset.

Convention 13.18 (Phosphorus only)**.** [A] Every statement of this paper uses, as heteroatom chemistry, the phosphodiester of the tether and the bridges and nothing else. No metal, no cofactor, no exogenous acceptor and no oxidizing equivalent enters any numbered statement. Where a later chemistry is mentioned it is marked [E] and carries no proof weight.

Remark 13.19 (Mechanical carriers, and what they address)**.** [E] Curvature and lateral tension couple to tilt and to position, not to the orientational state. They therefore address the outward channel of Theorem 12.9 and not the inward one, and are noted here to make that separation explicit rather

than because they read anything.

14 Continuity

Proposition 14.1 (Each ingredient is a by-product)**.** [A] *For each clause of Definition 5.1, the feature supplying it and the purpose that feature serves otherwise:*

(a) the state space is the templating orientation, whose purpose is the encoding;

(b) the response is the difference in tether length, whose purpose is to reach two different bases;

(c) the path is the tether, whose purpose is to hold the base to its template;

(d) the separation is the rigidity of a fused aromatic against the mobility of an excitation, which is a property of the material;

(e) the energy source is external and requires nothing of the architecture but that it absorb.

None is an addition, which is Corollary 5.5.

Scholium 14.2 (What kind of argument this is)**.** A later origin for signalling would require these ingredients to have been present, lost, and independently regained. That is a parsimony argument and not a proof, and this is the sentence that says so.
What raises it above a preference is Theorem 10.7: no succession creates Inv and none restores what a succession removes, so the invariant that makes a later structure readable is one a predecessor must have carried. That is a constraint on histories rather than a history.
What keeps it below a demonstration is Theorem 10.6. The invariant is inherited; the mechanism is not. This paper's only exhibited readout is conformational and electronic, and clause (c) of that theorem says precisely that such properties have no image in Inv. The continuity established here is therefore continuity of an addressable structure and not of a working channel, and the two should not be conflated.

Remark 14.3 (What would refute continuity)**.** [A] An ingredient of Theorem 5.4 shown to be a later addition, which would refute Corollary 5.5 while leaving the adequacy theorem standing; or a route by which Inv is created rather than inherited, which would refute Theorem 10.7 and with it the constraint on histories.
Neither is refuted by exhibiting a later structure that signals differently. Difference of mechanism is what Theorem 10.6 predicts.

15 Consolidated register

This section states in one place what the account answers and on what. It adds nothing. Its purpose is that a reader who has followed the argument should be able to see, without reassembling it, which answers are finite, which rest on a premise, and which are open.

15.1 What is answered, and on what

Does the architecture have what a signalling system requires?
Yes, on the five clauses of Definition 5.1, and without any component the integrated synthesis does not produce.
Rests on: Thm. 5.4, Cor. 5.5.
Standing: [D] Established on a deliberately weak definition (Sch. 5.7).

Is a carrier available at the onset?
Yes, one: the photon. The chromophore is the vessel skeleton and requires no development, no gradient, no pump and no partner.
Rests on: Prop. 13.1, Rem. 13.2.
Standing: [C] Imported; the photophysical parameters are H4.

What does the readout use?
Chromophore, bridge and acceptor: the vessel skeleton, the phosphodiester tether, and the templated base. Nothing is added.
Rests on: Prop. 13.4, block W3.
Standing: [E] Mechanism imported; the inventory is finite.

Is the state distinguishable by that readout?
The pair type is, at a transfer-rate ratio of 45 to 142 from a three-atom difference in bridge length. The presented face is not.
Rests on: Thm. 13.5, Thm. 13.14.
Standing: [A] Computed, blocks W1 and W3. One bit per anchor, not two.

Does the singlet serve?
No. The transfer rate is at or below the singlet decay rate and the states are unresolved. The readout requires the long-lived triplet.
Rests on: Finite (Thm. 13.9).
Standing: [A] Computed, block W2. A derived requirement on the architecture, falsifiable by measurement.

Can the membrane be addressed at all?
Not by position, and not by state-selective stimulus. It is read: the stimulus illuminates and the response discriminates.
Rests on: Prop. 7.1, Rem. 7.2.
Standing: [D] Established; the framing correction is recorded where it was made.

What does one window report?
The composition of a contiguous subword — the count of each anchor type — and not its arrangement.
Rests on: Thm. 7.5, Thm. 7.6.
Standing: [D] Derived; ℓ computed at block V2.

What sets the window length?
The optical length scale divided by the helical pitch, 3.57 nm. Two independent arguments give that spacing: the phase filter of the enclosure paper and the steric width of a unit.
Rests on: Finite (block V2).
Standing: [A] Computed. $\ell = 30$ diffraction-limited, 6 near-field.

Can the word be recovered from the compositions?
Yes, to within a fibre of exactly $\binom{\ell}{S_1}$: the word is fixed by its first ℓ symbols together with the observed differences.
Rests on: Thm. 12.2.
Standing: [D] Established; the closed form checked against exhaustive enumeration.

Does the ambiguity grow with the sequence?
No. It is bounded by the window: eight bits at $\ell = 10$, whether the strand carries a hundred anchors or a thousand.
Rests on: Cor. 12.3.
Standing: [A] Computed, block V5. The overlap of the windows is what does it.

Does the framework depend on the carrier?
No. Every statement enters a carrier through a response vector and a length scale only.
Rests on: Thm. 8.5.
Standing: [D] The licence for the whole deferral of chemistry; its proof is to be given as a checkable list.

Can a loop close on the orientational state?
No. The inward path is electronic and fast, the outward path conformational and slow, and reorientation is seven orders slower than either.
Rests on: Thm. 12.9, Cor. 12.10.
Standing: [D] Established. The architecture is a readable memory, not a controller.

What survives a replacement of the scaffold?
The adjacency, the orientation pattern and the symmetry type. Not the chirality, not the two-sidedness unless the successor has it, and not the conformational freedoms on which this paper's own readout stands.
Rests on: Thm. 10.4, Thm. 10.6.
Standing: [D] Established under non-degeneracy (H3).

Is succession reversible?
No. The category is directed: no morphism creates the invariant and none restores what a succession removes.
Rests on: Thm. 10.7.
Standing: [D] Established. It is what gives the continuity claim a shape.

What size of aperture does a closed aggregate admit?
From 0.70 nm at six units to 2.00 nm at twelve, lined by the phosphodiester arms that bound it.
Rests on: Finite (Thm. 11.2, Cor. 11.3).
Standing: [A] Computed, block V4. Topological; no conductance is claimed.

Is continuity proved?
No. A parsimony argument is given, constrained by the directedness of succession, and the mechanism is not inherited even where the invariant is.
Rests on: Sch. 14.2.
Standing: [A] Refused as a proof at Prop. 3.1(viii).

Does anything read the membrane?
Not established. A reading protocol is exhibited; no process of the corpus is shown to perform it.
Rests on: —
Standing: [A] Open (Target 18.9).

15.2 How much is finite

Remark 15.1 (The kinds, counted)**.** [A] Of the seventeen entries above, six are finite computations over imported geometry and stand whatever becomes of any premise: the transfer rates, the singlet–triplet comparison, which bit is resolved, the window length, the kernel bound, and the aperture sizes. Eight are derived under named premises. One is imported, one is refused, and one is open.
The distribution merits comment. This paper's finite content is arithmetic over quantities the enclosure paper computed — a bridge length, a footprint, a helical pitch — and it yields results that paper had no occasion to seek. Publication of the underlying geometry is what makes such derivations available to subsequent work.

Remark 15.2 (Where the premises are concentrated)**.** [A] Four premises carry everything that is not arithmetic: the regime (H1), the bounded self-perturbation (H2), the non-degeneracy of successions (H3), and the photophysical parameters (H4).
Of these, H4 is the only one that a measurement could settle outright and the only one whose failure would be quantitative rather than structural. H1 is contested *within the corpus*, by Remark 9.5. H2 is stated without a calculation. H3 is a convenience whose rarity is not shown. A reader allocating scepticism should allocate it in that order.

15.3 What the account looks like at each failure

H1, the regime. Under dispersal the window is a statistical rather than a fixed set, the composition observable an expectation rather than a count, and Corollary 12.3 holds with the fibre replaced

by a confidence set. The account weakens and does not fall. Remark 9.5 bounds it.

H2, the self-perturbation. If a readout disturbs the folding or the face freedom on which the enclosure paper's premises stand, then reading destroys the state, and the channel is single-use per anchor. Every statement about a single readout survives; nothing about repeated interrogation does.

H3, non-degeneracy. A degenerate succession collapses the adjacency and carries no invariant. Sections 10 and 11 are then about a subclass whose measure is unknown, and the continuity argument is about that subclass only.

H4, the photophysics. A β at the high end, or a triplet quenched by the acyl environment, compresses the contrast of Theorem 13.5 toward unity and the readout toward nothing. This is the failure a measurement would find first.

H5, the imported record. The geometry of Articles 61 and 62. Its failure moves numbers throughout and removes no statement, every theorem being stated in terms of a bridge length and a footprint rather than of their values.

> **Scholium 15.3** (Is there a trapdoor?)**.** The corpus's practice is to ask whether any failure leaves the account intact and its conclusion false. Here there is one, and it should be named rather than discovered.
>
> If H4 fails — if the contrast is unity — then every structural statement of this paper stands. The five ingredients are still present, the window is still contiguous, the fibre is still $\binom{\ell}{S_1}$, succession is still directed, and no loop still closes. What fails is only that the response vector distinguishes nothing, and with it Definition 5.1(b), quietly, in a clause whose failure the rest of the paper is not arranged to reveal.
>
> That is the trapdoor and it is a narrow one, because H4 is measurable and the measurement is not difficult. But a reader should know that the paper's mathematics is largely independent of whether its physics discriminates anything, and that this independence — which is Theorem 8.5, the paper's own keystone — is what makes the trapdoor possible.

16 Falsification register

Each entry names what would refute the statement and only that. Where a statement falls with another, that is said rather than an entry invented for it.

Theorem 5.4
An ingredient of Definition 5.1 shown absent: a state that does not persist over a readout, a response that does not discriminate, a path that does not carry, a separation that does not hold, or no external energy source.

Corollary 5.5
An ingredient present only by an addition the integrated synthesis does not produce. This refutes the continuity argument while leaving Theorem 5.4 standing, and is the more likely attack.

Theorem 6.2
An orientational lifetime within three orders of the readout window, which would remove the adiabatic separation; or a process omitted from Table 1 that is fast against the state and slow against the readout.

Remark 6.3
An anchoring in which units exchange positions along the strand, which would require the covalent backbone to permute its residues.

Theorem 7.5, Theorem 7.6
A stimulus addressing a non-contiguous set of anchors; or a readout resolving individual units within a window, which would return an arrangement rather than a composition and would make the kernel trivial.

Theorem 13.5, Theorem 13.9
A through-bond attenuation outside 1.0 to 1.3 Å^{-1}; a triplet quenched in the acyl environment to a lifetime near the transfer time; or a transfer rate independent of bridge length, which would remove the discrimination entirely.

Theorem 13.14
An observable dependence of the transfer rate on the presented face, which would resolve the second bit and strengthen the paper; or a face-dependent through-bond distance, which the fixed bond count excludes.

Theorem 8.5
A statement of Sections 6 to 12 depending on a property of the carrier other than its response vector and its length scale. This is the paper's keystone and its refutation makes every result conditional on a particular chemistry.

Theorem 12.2, Corollary 12.3
A recomputation at block V5 disagreeing with $\binom{\ell}{S_1}$; or a readout by disjoint rather than overlapping windows, under which the kernel grows with the strand and the bound fails.

Theorem 12.9, Corollary 12.10
A path by which the sequence writes the orientational state on a signalling timescale, which would close the loop and make the architecture a controller. This is the paper's sharpest claim and therefore its most exposed.

Theorem 10.4, Corollary 10.5
An addressing depending on a property of the assembly outside Inv, which would break the inheritance.

Theorem 10.6
A succession carrying chirality to an achiral occupant, or a two-bit orientation to a one-sided one; either would be a morphism transporting a property the functor does not record.

Theorem 10.7
A route by which Inv is created rather than inherited, or by which a scaffold's conformational freedoms are recovered from

its successor. This also refutes the constraint on histories at Scholium 14.2.

Theorem 11.2, Corollary 11.3
A recomputation at block V4 disagreeing; or a closed cycle of fewer than six units at the stated width, which the contact condition excludes.

Corollary 9.4, Remark 9.5
A demonstration that aggregation does not fix relative positions, which would remove the inversion and leave the two papers wanting the same branch.

17 Precedence

Ruling 17.1 (Disposition against the enclosure paper)**.** [A] *Consistent, extending. The injection, the anchor ordering, the tether lengths, the footprint and the helical filter are imported unamended, and that paper's declination of a decoder is this paper's starting point rather than a statement amended here. No result of that paper is superseded.*

Remark 17.2 (What the enclosure paper may now cite)**.** [A] Three entries, of which two were not available to it.
That the covalent ordering of its anchors, which it obtained for no premise, also excludes lateral diffusion from the timescale hierarchy of any readout (Remark 6.3). That paper used the ordering to make the surface hold a word rather than a bag; it also makes the word readable.
That the three-atom difference between its two tethers is an exponential difference in transfer rate, a factor of 45 to 142 (Theorem 13.5), so the datum it called chemically carried is carried in a form something could use.
And that its helical pitch and its unit footprint give the same anchor spacing by two independent routes (block V2), which neither paper had reason to expect.

Remark 17.3 (A coordination finding: the two papers want opposite branches)**.** [A] The enclosure paper assumes dispersal and records that aggregation would replace its subject. This paper finds that aggregation raises its addressing resolution (Corollary 9.4). The branch is one hypothesis and the two papers want opposite values of it.
The finding belongs in the coordination ledger and not in either paper's argument. It says that the regime question is load-bearing twice in opposite directions, that settling it will cost one of the two accounts something, and that a corpus letting each paper assume the branch that suited it would be concealing the trade. Remark 9.5 bounds what each would lose.

Ruling 17.4 (Disposition against the residue account)**.** [A] *Consistent; one consequence added. The chirality that account transfers from the sugar to the residue is a property of an occupant and not of an arrangement, so it lies outside* Inv *and by Theorem 10.6(b) is not carried by a succession to an achiral occupant. The consequence attaches to any later structure claimed to inherit from this one and bears on no result obtained there.*

18 Targets, and conclusion

18.1 Targets, aggregated

The targets are given in the order in which settling them would do most for the account, which is not the order in which they arise. The first is a measurement and the rest are not.

Target 18.1 (The photophysics)**.** Measure the through-bond attenuation coefficient β of the phosphodiester bridge and the triplet lifetime of a chrysene unit in an acyl environment. These are H4, and by Scholium 15.3 they are the only premise whose failure would leave every structural statement of this paper standing and its subject gone. They are also the only premise a single measurement settles.

Target 18.2 (The second observable)**.** Exhibit an observable sensitive to the depth of the base relative to the outer interface rather than to its bond count, which by Theorem 13.14 would resolve the presented face and carry the channel from one bit per anchor to two. Until one is exhibited the readout resolves half of what the enclosure paper's injection distinguishes.

Target 18.3 (The regime)**.** Decide dispersal against aggregation. It is H1, it is load-bearing in two papers in opposite directions (Remark 17.3), and settling it will cost one of the two accounts something. What each would lose is bounded at Remark 9.5.

Target 18.4 (Substrate-independence, as a list)**.** Give the proof of Theorem 8.5 as a statement-by-statement list, so that a reader may check the claim rather than accept it. It is the licence for the whole deferral of chemistry, and a hand-wave there would be fatal in a way a hand-wave elsewhere would not.

Target 18.5 (The self-perturbation)**.** Bound the disturbance a readout imposes on the rotamer population that carries the enclosure paper's conformational premises. It is H2, it is stated without a calculation, and its failure makes the

channel single-use per anchor.

Target 18.6 (The catalytic geometry)**.** Determine whether residues held at adjacent sites of an aggregate, of order 0.7 nm apart by block V3, are within bond-forming distance and orientation. It decides whether the catalytic realization of Remark 10.10 is available at all.

Target 18.7 (The contact energy)**.** Supply ε, the free energy of lateral aromatic contact per unit area in an acyl core. By Theorem 9.2 the line tension and the domain scale follow from it and from lengths already computed, so one number closes the section. Remark 9.3 says why this paper declines to estimate it from gas-phase values.

Target 18.8 (Non-degeneracy)**.** Determine whether degenerate successions are rare. It is H3, and its failure does not refute Sections 10 and 11 but restricts them to a subclass of unknown measure.

Target 18.9 (A reader)**.** Exhibit a process the corpus describes that consumes the observable of Definition 12.1. Until one is exhibited, this paper supplies a reading protocol and not a reader, and the capacity of Theorem 12.5 bounds a channel with no user.

18.2 Conclusion

Proposition 18.10 (What is established)**.** [A] *Subject to the register of Appendix A, and distinguished by kind:*

(i) The complex satisfies the five clauses of Definition 5.1, and no clause requires a component the integrated synthesis does not produce (Theorem 5.4, Corollary 5.5).

(ii) The framework is hybrid by necessity and reduces on a separation of seven orders between the orientational lifetime and the readout window (Theorems 6.1, 6.2). Lateral diffusion does not enter, the anchors being held in order by a covalent backbone (Remark 6.3).

(iii) The architecture is a state-discriminating detector and not a state-selective filter (Remark 7.2); a window reports a composition and not an arrangement (Theorem 7.6); and the window length is the optical scale divided by the helical pitch, which two independent arguments fix at 3.57 *nm (block V2).*

(iv) The readout uses only the vessel skeleton, the phosphodiester tether and the templated base. The three-atom difference between the tethers is an exponential difference in transfer rate, a factor of 45 *to* 142 *(Theorem 13.5), and the readout requires the long-lived triplet and not the singlet (Theorem 13.9).*

(v) It resolves the pair type and not the presented face, the through-bond distance being fixed by bond count (Theorem 13.14), which reproduces the enclosure paper's division for an independent reason (Corollary 13.15).

(vi) The word is recoverable from overlapping window compositions to within a fibre of exactly $\binom{\ell}{S_1}$, an ambiguity bounded by the window and not by the strand (Theorem 12.2, Corollary 12.3).

(vii) No feedback loop closes on the orientational state: the inward path is electronic and fast, the outward conformational and slow, and reorientation is seven orders slower than either (Theorem 12.9, Corollary 12.10). The architecture is a readable memory and not a controller.

(viii) Succession preserves the adjacency, the orientation pattern and the symmetry type, and nothing else; chirality, two-sidedness and the scaffold's conformational freedoms are provably not inherited (Theorems 10.4, 10.6); and the category is directed (Theorem 10.7).

(ix) A closed aggregate of six units admits an aperture of 0.70 *nm and of twelve an aperture of* 2.00 *nm, lined by the phosphodiester arms that bound it (Corollary 11.3). The statement is topological and no conductance is claimed.*

Remark 18.11 (What is not established, restated)**.** [A] No pathway, no reader, no successor and no history.
The paper exhibits a reading protocol and shows that nothing in the corpus is known to perform it. It exhibits a succession functor and shows that the existence of any successor is a premise. It gives a parsimony argument for continuity and labels it. And it establishes that the mechanism it computes is precisely the kind of property its own succession theorem says is not inherited, so that what continuity it argues for is continuity of an addressable structure and not of a working channel.

Scholium 18.12 (What would overturn the paper)**.** Three findings, of quite different weights, and the order is not that of their probability.
A contrast of unity — a β at the high end or a quenched triplet — would leave every structural statement standing and remove the subject, by Scholium 15.3. It is the most probable of the three and the least conspicuous.

> A failure of Theorem 8.5 would make every result conditional on a particular chemistry and would convert a framework into a case study. It is the most damaging to the paper's method.
> And an exhibited loop closing on the orientational state would refute Corollary 12.10, the most specific claim advanced here and correspondingly the most exposed. It would also be the most informative of the three: a framework that excludes a possibility and is then shown to be wrong has been making a testable assertion.

A Hypothesis register

	premise	**what rests on it**	**what survives its failure**
H1	Units aggregate rather than disperse, so that a window is a fixed set of sites (Cor. 9.4).	The precision of Thm. 7.5; the composition observable as a count rather than an expectation.	The whole account in weakened form: the window becomes statistical, the observable an expectation, and the fibre of Cor. 12.3 a confidence set. Contested within the corpus (Rem. 17.3).
H2	A readout leaves the rotamer population carrying the enclosure paper's conformational premises standing (Rem. 8.7).	Repeated interrogation of one anchor.	Every statement about a single readout. The channel becomes single-use per anchor.
H3	Successions are non-degenerate: injective on sites (Hyp. 10.3).	Thm. 10.4 and everything in Secs. 10 and 11.	Those sections restricted to a subclass whose measure is unknown; the continuity argument restricted with them.
H4	The photophysical parameters: β between 1.0 and 1.3 Å^{-1}, and a triplet lifetime long against the transfer time — which by Thm. 13.10 is a property of the setting's oxygen content and not of the chromophore.	Thm. 13.5 and Thm. 13.9, and through them the discrimination of any state at all.	Every structural statement of the paper, and no subject for them — the trapdoor of Sch. 15.3. The only premise a single measurement settles.
H5	The noise model of Def. 12.1: counting statistics of the decay, thermal fluctuation of the slow variables.	The finite-photon correction to Thm. 12.5.	The noiseless capacity and the exact fibre of Thm. 12.2, which are combinatorial.
H7	The strand is locally extended along the surface over a window (Hyp. 7.4).	Thm. 7.5, and through it the window sums and the reconstruction of Thm. 12.2.	Nothing in Secs. 6, 8 or 13. A coiled strand gives spatially contiguous regions over sequence-discontiguous sets and the reconstruction fails.
H6	The imported record: the tether lengths, the footprint, the helical pitch and the anchor ordering of the enclosure paper.	Every number in Appendix B.	Every theorem, each being stated in terms of a bridge length and a footprint rather than of their values.

Remark A.1 (The dependency, in one sentence)**.** 🄰 H4 carries the subject and nothing else carries it; H1 carries the precision and is contested elsewhere in the corpus; H3 carries the scope of the succession sections; H2 carries repetition; H5 carries a correction; H6 carries the numbers and not the statements. A reader who denies H4 keeps the whole mathematics and loses everything it was about, which is the asymmetry Scholium 15.3 exists to name.

B Verification

Each block recomputes its claim from an explicit structure and emits its own numbers. Nothing quantitative in the body is asserted; every such statement is transcribed from a block below. The blocks are emitted by `acf-63-blocks.py`, which requires the geometry of the enclosure paper and computes nothing from it that paper did not print.

V1 [COMPUTED] **Characteristic times and the separations**

Every process of Table 1, with the separation that licenses the reduction and the note on why lateral diffusion is absent.

```
process                          time (s)     note
-------------------------------------------------------------------------
photon absorption                  1.0e-15    instantaneous on every scale
```

```
vibrational relaxation             1.0e-12
intersystem crossing to T1         1.0e-08    sets the delay before readout
arm rotamer transition             1.0e-08    the conformational path
electron transfer, T_A tether      2.2e-07    block W2, beta = 1.15
strand internal fluctuation        1.0e-06    anchors are tethered, not free
electron transfer, T_C tether      1.7e-05
triplet decay, unquenched          1.0e-03    the measurement window
orientational reversal             1.0e+04    the state to be read
-------------------------------------------------------------------------

SEPARATION THAT LICENSES THE REDUCTION
  state persistence / measurement window = 1e4 / 1e-3 = 1e7
  the orientational word is frozen over a readout by seven orders

LATERAL DIFFUSION, and why it is absent.  Free diffusion of a unit over an
anchor spacing would take of order a microsecond, which is NOT slow against
the readout and would spoil the reduction.  It does not enter because the
anchors are held in order by the covalent backbone: what fluctuates on that
timescale is the strand's internal geometry, not the order of the anchors.
The ordering established without premise in the enclosure paper is therefore
load-bearing here as well.
```

V2 [COMPUTED] The window length

The optical length scale of the stimulus against the spacing of engaged anchors, and the resulting bits lost to the kernel of Corollary 12.3.

```
anchor spacing along the strand  : 0.34 nm   (one per base pair)
ENGAGED anchor spacing           : 3.57 nm   (one per helical turn)

The engaged spacing is the one that matters, and TWO independent arguments
give it.  The helical filter of the enclosure paper admits only anchors in
phase, one per turn.  And a unit is 0.74 nm across and cannot sit 0.34 nm
from its neighbour.  The phase condition and the steric limit agree.

  stimulus                    spot (nm)   l = spot/pitch   bits lost
  ---------------------------------------------------------------------
  diffraction limited, 300 nm     107.0          30          27.21
  evanescent / TIRF                50.0          14          11.74
  near-field aperture              20.0           6           4.32
  tip-enhanced                      5.0           1           0.00
  ---------------------------------------------------------------------

l is the ratio of the optical length scale to the HELICAL PITCH, not to the
base-pair rise.  A diffraction-limited stimulus loses a quarter of a
hundred-anchor word and a fortieth of a thousand-anchor one.
```

W1 [COMPUTED] Electron transfer along the tether

Donor–acceptor separation from the bond count of each tether, and the transfer rate at three values of the through-bond attenuation coefficient.

```
chromophore : the chrysene skeleton         (present from the onset)
bridge      : the phosphodiester tether     (present as the tether)
acceptor    : the nucleobase                (present by the templating)
k0 = 1e13 /s contact-limited;  backbone rise 1.27 A per atom

T_A  10 bonds -> R = 12.70 A
T_C  13 bonds -> R = 16.51 A        dR = 3.81 A

  beta      k_ET(A)      k_ET(C)    rate ratio
  ------------------------------------------------
  1.00    3.051e+07    6.758e+05        45.2
  1.15    4.541e+06    5.679e+04        80.0
  1.30    6.758e+05    4.772e+03       141.6
  ------------------------------------------------

The ratio is exp(beta.dR): 45 to 142 over the range.  The PAIR TYPE is
therefore reported as a rate, by the bond count alone.
```

W2 [COMPUTED] The singlet, the triplet, and the oxygen of the setting

The transfer rates against a singlet decay of ten nanoseconds and against a triplet whose lifetime is set by the oxygen content of the acyl core.

```
SINGLET   tau0 = 10 ns
  beta     tau_A       tau_C      tau_unquenched   contrast
  ------------------------------------------------------------
  1.00     7.66 ns     9.93 ns       10.00 ns        1.3x
```

```
  1.15     9.57 ns     9.99 ns       10.00 ns        1.0x
  1.30     9.93 ns    10.00 ns       10.00 ns        1.0x
  ------------------------------------------------------------
The states are not resolved on the singlet at any beta.

TRIPLET, as a function of the core oxygen content.  O2 partitions into an
acyl core at 3-5x its aqueous concentration and quenches an aromatic triplet
at k_q ~ 2e9 /M/s, so the operative lifetime is a property of the SETTING.
(beta = 1.15 throughout)

  core [O2]            k_O2 (1/s)   tau_T      tau_A      tau_C    tau_A/tau_C  tau_T/tau_A
  ------------------------------------------------------------------------------------------
  air-saturated ~1 mM   2.00e+06   500.0 ns   152.9 ns   486.2 ns      3.2          3.3
  ~100 uM               2.00e+05    5.00 us   210.9 ns    3.89 us     18.5         23.7
  ~10 uM                2.00e+04   50.00 us   219.3 ns   13.02 us     59.4        228.0
  ~1 uM                 2.00e+03  500.00 us   220.1 ns   17.01 us     77.3       2271.4
  anoxic ~0.1 uM        2.00e+02    1.00 ms   220.2 ns   17.30 us     78.6       4541.8
  rigid, deoxygenated   0.00e+00    1.00 ms   220.2 ns   17.30 us     78.6       4541.8
  ------------------------------------------------------------------------------------------

  crossover at a tenfold discrimination : [O2] = 221 uM

READING.  The 1 ms figure is a rigid-deoxygenated one and is not the figure
that applies in a fluid core.  The tether discrimination falls from 79x
anoxic to 3.2x air-saturated, a factor of 25, and the unquenched reference
ceases to be useful at all.

THE READOUT REQUIRES AN ANOXIC SETTING.  This is a constraint on the era and
not a defect of the architecture: the same atmospheric oxygenation that
would later make a sterol reachable is what closes this channel.
```

W4 [COMPUTED] The base-dependent term, and whether it confounds

The chemical contribution to the discrimination, against the geometric one.

```
The two anchors differ in TWO ways at once: the adenine anchor has the
shorter bridge (10 bonds) and bears a PURINE; the cytosine anchor the longer
bridge (13 bonds) and a pyrimidine.  Purines are the better donors.
Oxidation potentials vs NHE: G ~1.29, A ~1.42, C ~1.6, T ~1.7 V, so adenine
is easier to oxidise than cytosine by about 0.2 eV.

 dG difference   barrier share   chemical factor   geometric factor
 ------------------------------------------------------------------
  0.10 eV            0.25              2.6              80.0
  0.10 eV            0.50              7.0              80.0
  0.15 eV            0.25              4.3              80.0
  0.15 eV            0.50             18.5              80.0
  0.20 eV            0.25              7.0              80.0
  0.20 eV            0.50             49.0              80.0
  0.25 eV            0.25             11.4              80.0
  0.25 eV            0.50            129.5              80.0
 ------------------------------------------------------------------

READING.  At 0.2 eV and a barrier share of a quarter to a half the chemical
factor is 7 to 49 against a geometric factor of 80.  THE TWO ARE OF THE SAME
ORDER AND RUN IN THE SAME DIRECTION.

CONSEQUENCE.  The discrimination is their product, of order 500 to 4000 --
larger than either alone, which is favourable.  What is NOT available is the
attribution: the discrimination cannot be called a by-product of the
templating geometry when a comparable part of it is a by-product of base
identity.

A DISCRIMINATING TEST.  Compare the same base at the two bridge lengths, or
the two bases at one length.  Either separates the terms, on a model
compound, by ordinary photophysics, and neither requires the architecture.
```

W3 [COMPUTED] Which bit the channel resolves, and what is deferred

The dependence of the observable on each of the two orientational data, and the inventory of what the readout uses.

```
The donor-acceptor separation is fixed by the BOND COUNT and is the same
whichever face the unit presents.  Hence:

  alpha  (pair type, 10 bonds against 13)   READ.   rate ratio 45-142;
                                                    lifetimes separated by
                                                    two to four orders
  beta   (presented face)                  NOT READ by this observable.
```

```
                                                The base stands at the
                                                same through-bond
                                                distance either way.

This reproduces the division the enclosure paper found -- the pair type
carried unconditionally, the presented face only under a further condition --
for an INDEPENDENT reason: a bond count against a depth.  A second observable
sensitive to the depth of the base relative to the outer interface would
resolve beta; none is selected here.

INVENTORY OF THE READOUT
  chromophore   chrysene skeleton        present from the onset
  bridge        phosphodiester tether    present as the tether
  acceptor      nucleobase               present by the templating
  stimulus      photon                   external; no gradient, pump or
                                         partner required
Nothing is added.  No metal, no cofactor, no exogenous acceptor, no
oxidizing equivalent.  Divalent cations are deferred with the sterol
transformation and are used in no numbered statement.
```

V3 [COMPUTED] The aggregation criterion

The lateral contact a unit offers a neighbour, against the area it occupies.

```
unit footprint in the plane         : 0.39 to 0.43 nm^2   (Article 62)
effective diameter                  : 0.74 nm
stacking face available laterally   : 1.25 x 0.70 = 0.88 nm^2
ratio of stacking face to footprint : 2.03

READING.  The face a unit presents laterally is about TWICE its footprint in
the plane, and it stands with the membrane normal in its plane, so the face
is available to a neighbour without any reorientation.  That is the
geometric content of the tension the enclosure paper records: a large
contact area left unused under the dispersed regime.  Whether it is used is
H2 and is not settled here or there.
```

V4 [COMPUTED] Pore geometry of a closed aggregate

Ring radius and aperture for a closed cycle of units in mutual contact.

```
unit width presented in the plane: 0.70 nm
ring of n units, adjacent units in contact:
    R = d / (2 sin(pi/n)),     aperture radius = R - d/2

  n     ring R (nm)   aperture radius   aperture diameter (nm)
  ------------------------------------------------------------
   6         0.70            0.35                0.70
   7         0.81            0.46                0.91
   8         0.91            0.56                1.13
  10         1.13            0.78                1.57
  12         1.35            1.00                2.00
  16         1.79            1.44                2.89
  20         2.24            1.89                3.77
  ------------------------------------------------------------

The smallest closed ring is six units and encloses 0.70 nm; twelve enclose
2.00 nm.  The aperture is lined by the phosphodiester arms of the units
bounding it.

NOTHING HERE CLAIMS A CONDUCTANCE.  The statement is topological -- a closed
cycle gives the complement genus one within the patch -- and the numbers say
only what size of hole the geometry admits.
```

V5 [COMPUTED] Reconstruction from window sums

The exact fibre of the window-composition map, its closed form, and a brute-force check of that form against exhaustive enumeration.

```
The photonic readout resolves the PAIR TYPE only (block W3), so the word is
binary.  A window of length l reports the COMPOSITION of that window and not
the arrangement.  Sliding gives S_i = w_i + ... + w_{i+l-1}.

EXACT FIBRE.   S_{i+1} - S_i = w_{i+l} - w_i,
so the word is fixed by its first l symbols together with the differences,
and the consistent words are those whose first l symbols sum to S_1:

      fibre size = C(l, S_1),     max over S_1 = C(l, floor(l/2)).
```

```
  l     max fibre    bits lost    retained of m=100
  ---------------------------------------------------
  2             2         1.00             99.00
  3             3         1.58             98.42
  5            10         3.32             96.68
  8            70         6.13             93.87
 10           252         7.98             92.02
 16         12870        13.65             86.35
 20        184756        17.50             82.50
  ---------------------------------------------------

BRUTE-FORCE CHECK (all binary words; fibres of the window-sum map)
  m    l    max fibre   C(l,l/2)   agree
  -----------------------------------------------
  8    3            3          3   yes
  8    4            6          6   yes
  8    5           10         10   yes
 10    3            3          3   yes
 10    4            6          6   yes
 10    5           10         10   yes
 12    3            3          3   yes
 12    4            6          6   yes
 12    5           10         10   yes
  -----------------------------------------------

READING.  The ambiguity is bounded by the WINDOW and does not grow with the
strand: a hundred anchors through windows of ten are recovered to within
eight bits, and a thousand to within the same eight.  The kernel is a fixed
cost and not a rate of loss.  The overlap of the windows is what does it; a
readout by disjoint windows would lose the arrangement in every one and the
kernel would grow.
```

V6 [COMPUTED] Bandwidth

The ceiling on the readout rate imposed by the triplet lifetime, and the time to read a strand of stated length.

```
a window cannot be read faster than the triplet decays
  triplet lifetime, unquenched     1.0e-3 s
  ceiling on window readout rate   1.0e+3 windows / s

time to read a strand of m anchors through m-l+1 overlapping windows,
at l = 30 (diffraction limited) and l = 6 (near field):

    m        windows (l=30)   time (s)     windows (l=6)   time (s)
  ------------------------------------------------------------------
     100              71        0.071             95        0.095
    1000             971        0.971            995        0.995
   10000            9971        9.971           9995        9.995
  ------------------------------------------------------------------

READING.  The readout is not rate-limited in any interesting sense: a
thousand-anchor strand is read in about a second.  What limits the channel
is the kernel of block V5 and not the bandwidth.

FINITE PHOTON NUMBER.  The composition is an amplitude ratio and not a count
(Rem. on what the measurement is), so the limit is the photon budget rather
than the triplet lifetime whenever the contrast is low:

  contrast r     (r-1)^2/(r+1)^2    photons for equal error
  ---------------------------------------------------------
    79 (anoxic)        0.95                   1.0 x
    18 (~100 uM)       0.81                   1.2 x
     3.2 (air)         0.27                   3.5 x
  ---------------------------------------------------------

Oxygen degrades the readout twice: through the contrast, and through the
shorter triplet lifetime that permits fewer excitations per unit time.
```

C Molecular commentary, isolated

Remark C.1 (Status of this appendix)**.** [A] Nothing here enters a numbered statement, and no statement of this paper is weakened by its removal. It is retained because the observations are natural ones for a reader to make at the points where the paper declines to make them.

Remark C.2 (The chromophore)**.** [E] Chrysene absorbs in the near ultraviolet and intersystem-crosses to a triplet whose lifetime in a deoxygenated and rigid environment is long. The readout of Section 13 requires that lifetime to survive the acyl core, where the environment is fluid and where molecular oxygen partitions strongly. Whether it does is H4 and is the paper's first target.

Remark C.3 (The acceptor)**.** [E] Nucleobases quench aromatic excited states by photoinduced electron transfer, the purines more readily than the pyrimidines. The paper uses only that a base quenches and an alkyl cap does not, and not any difference between bases; a base-dependent rate would add a term the model does not carry and would, if large, confound the length discrimination of Theorem 13.5 with a chemical one.

Remark C.4 (The bridge)**.** [E] The phosphodiester is a saturated bridge and the attenuation coefficients assumed for it are those of saturated bridges generally. A phosphate in the path may behave otherwise, and the sign of the deviation is not obvious: a polarizable centre may enhance coupling, and a charged one may raise the tunnelling barrier.

Remark C.5 (Cations, sterols, and the era they belong to)**.** [E] Both are deferred and for the same reason: each presupposes a network already in place. A cation–π readout requires coordination chemistry in a membrane saturated with phosphate; a sterol requires a ring contraction, nine carbons, an exhaustive reduction, eight stereocentres and an oxidizing environment.
The apertures of Corollary 11.3 are of ion-channel dimension and anionically lined, which is noted and used nowhere. What the succession framework adds to the observation is that a later architecture acquiring coordination chemistry would find the frame standing rather than having to build one — a statement about inheritance and not about occurrence.

D What was withdrawn in preparing this paper

Remark D.1 (Addressing as selection)**.** [A] An earlier form of Section 7 held that the stimulus *selects* a subset of states, and the framework was built as a matched filter returning a subset.
For the photonic carrier that is wrong. Absorption does not depend on the orientational state: the transition dipole lies in the molecular plane, and the flip that changes the presented face carries an in-plane dipole to its own negative, which absorbs alike. What discriminates is the response and not the stimulus.
The correction changes what the theorems say — a filter returns a subset and a detector returns a distribution — and the decoding problem of Section 12 is the second and not the first. Recorded at Remark 7.2.

Remark D.2 (The singlet readout)**.** [A] The readout was first computed on the singlet, where the contrast between the two tether lengths is between nought and thirty per cent and the states are not resolved. The triplet was adopted not by preference but because the arithmetic left no alternative, and the requirement is now Theorem 13.9. The withdrawal is recorded because the requirement reads as a designed feature and was not one.

Remark D.3 (The geometric attribution)**.** [A] An earlier draft attributed the discrimination between the two anchor types to the three-atom difference in bridge length alone, and made a point of it: that a structure designed to be read could hardly have done better than to place such a difference in a bridge whose attenuation is exponential.
The claim is withdrawn. The two anchors differ also in the base they carry, a purine against a pyrimidine, and by Theorem 13.6 the chemical term is of the same order as the geometric one and runs in the same direction. The discrimination is therefore larger than the earlier draft computed and is not attributable as that draft attributed it.
What survives is Corollary 13.7 and a test: compare one base at two bridge lengths, or two bases at one. The withdrawal is recorded because the withdrawn claim was among the more persuasive in the paper and rested on a premise that does not hold.

Remark D.4 (A carrier comparison table)**.** [A] An earlier draft compared three carriers — photons, divalent cations, mechanical strain — on four properties, and left the selection open. The comparison is withdrawn. Only one carrier is available to the architecture without a development it has not had, and a table implying a choice among three misdescribed the situation. Cations are deferred at Remark 13.17; mechanical strain addresses the outward channel only, which is now stated where that channel is (Remark 13.19).

E Sources, by use

Remark E.1 (Status of this appendix)**.** [A] A concordance, provided so that the provenance of each imported statement may be checked without recourse to the source articles. It enters no proof.

source	used at	what is taken
enclosure paper [Sch26b]	Not. 2.3, Sec. 4, blocks V2–V4	The anchor set and its covalent ordering; the two tether lengths, ten bonds and thirteen; the orientational datum and its injection; the unit footprint and stacking face; the helical filter. Every number in Appendix B descends from these.
residue account [Sch26a]	Rul. 17.4	The transfer of chirality from the sugar to the residue, against which Thm. 10.6(b) is stated. No result is drawn from it.
coordinating paper [Sch26c]	Sec. 2	The status labels and the four-level convention separating connectivity, admissibility, accessibility and realization.
outside the corpus	Thm. 6.2, Thm. 13.5, Thm. 12.2	The reduction for piecewise-deterministic processes; the photophysical parameters of Appendix C; and the combinatorics of reconstruction from subword compositions, of which only the elementary case is used and that case is proved here.

Remark E.2 (What is not used)**.** [A] The seeding and refinement apparatus, the assignment machinery, the registry capacity and the parity obstruction are not drawn on. Nor is the enclosure paper's scission, its carbon ledger or its closure arithmetic: this paper takes that paper's *geometry* and none of its chemistry.

References

[Dav93] M. H. A. Davis. *Markov Models and Optimization*. Chapman & Hall, London, 1993. Piecewise-deterministic Markov processes and the averaging of fast variables; used at Theorem pdmp, which imports the reduction rather than reproving it.

[Sch26a] Charles D. Schaper. Configuration at the Transannular Centre: Uniformity of the Selected Branch over the Structure Series, and the Descriptor Pattern of the Twenty. *Annals of the Chrysene Formalism*, 1(3):1250–1278, 2026. Article 61. DOI: https://doi.org/10.68366/qf0vze43.

[Sch26b] Charles D. Schaper. The Enclosure via the Encoded Chrysene Cluster: Integrated Synthesis of Nucleic Acids and Phospholipids, and the Orientational Encoding of the Membrane. *Annals of the Chrysene Formalism*, 1(3):1279–1320, 2026. Article 62. DOI: https://doi.org/10.68366/24m3wx88.

[Sch26c] Charles D. Schaper. The Origins Arc: A Coordinating Formalism for the Passage from the Substituted Chrysene Cluster to the Genetic Code. *Annals of the Chrysene Formalism*, 1(3):1163–1249, 2026. Article 60. DOI: https://doi.org/10.68366/z2fwpm73.