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# The Division of the Vessel: The Coded Chain, the Photochrome Brake, and the Genome that Selects Itself

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**Abstract.** This article states the conditions under which a protocell of one tetrasubstituted chrysene family divides.
The residue formed at the chrysene is esterified to the 2′- or 3′-hydroxyl of its own tether ribose and linked from there into a chain, so no excision puts a particle into the lumen. A chain reaches the lumen only on release, and only a stop word releases it: there a trapped structure frees the tether phosphate on the chrysene side, and that phosphate, staying bound to its adenosine, hydrolyses the chain transferred onto its hydroxyl. The lumen particles of a period are the released chains and the residues hydrolysed before they joined, and nothing else. This fixes the gain, and with it the vessel's shape: at the stop sets of the observed codes it lies between 0.0588 and 0.5389, so the orbit of the integrated cycle exists with a wide margin.
Division then needs four conditions: the orbit must exist; each daughter must receive enough lipid to close a minimal anchored enclosure, which is shown to confine fission to dusk and to nothing else; replication must have finished; and fission must be withheld until then. The fourth is the one the corpus lacked. Nothing inside the vessel can mark dusk, the shape and every bulk concentration being slaved to the gain; and, treated as escape over a barrier, no barrier of fixed height both holds through the period and fires at dusk, whatever its height and whatever the attempt rate.
The brake is the photochrome, a substituted *trans*-azobenzene derived from the 6,12-disubstituted chrysene: activated by the forcing it holds fission, and when the forcing ends it relaxes and releases. The timing is then exogenous, and division at dusk, which the corpus has carried as a definition, becomes a consequence. The brake must supply 4.09 to 10.73 $k_BT$; the admissible connector population commands 10.3 to 46.8 $k_BT$. The same population that was short by four to fifty times as a driver of shape is ample as a brake, a brake being priced against a difference and a driver against the whole.
Released at every dusk, the brake would divide every vessel. Two further inputs decide whether a given one does. The first is the extent of membrane-retained polypeptide, which sits at a constant level the genome fixes. The second is the genome: both strands of the duplex are tethered into the bilayer and a daughter needs a whole duplex, so division waits on replication, and it need not be made to, separation requiring the switch in the state that holds fission. The anchors then shape what divides. An anchored duplex pays exactly Article 62's bending tolerance $E^*$ on its own minimal enclosure and less on anything flatter, so two of them, demixed to opposite poles, flatten the poles and leave the curvature between them, with 6 to 60 $k_BT$ to spend on the choice of shape. They fix the axis of the neck and assign one duplex to each daughter; they do not close it, the domains being patches and not hemispheres.
Three conditions then bound the genome: it must express often enough to hold the gate, exceed the packing floor, and be short enough for replication to finish within the forcing. The band between them is non-empty at every rate the corpus carries, and a genome outside it does not divide at all: it grows, loses nothing, and leaves no lineage. The discriminator is the length of the genome and the frequency of its expression, not any rate, and the verdict is inherited.

**Keywords:** cell division; photochrome; azobenzene; tethered duplex; division gate; stop word; esterified residue; genome length; expression density; self-filtering genome; Chrysene Formalism

## 1 Introduction

### 1.1 What the preceding articles left

Article 72 [Sch26c] showed that a lineage keeping one strand per vessel comes to consist of closure vesicles dividing symmetrically at dusk, on an orbit that exists if and only if the gain $g$ does not exceed one. The gain was computed from Article 71's loop [Sch26a], in which each accepted codon excises a residue into the lumen and a first-order condensation removes it again (Article 71, Hypotheses H6 and H7). Article 74 [Sch26d] found that at $g = 1$ the dusk shape is the two-sphere limit shape and fission costs only the Gaussian term, and that a lineage whose gain is too large is returned to the window by environmental lipid.

Two things were left. The gain at the corpus baseline, 1.8716, exceeds one, so the orbit as computed does not exist without help; and the premise that fixes the gain, a residue delivered to the lumen, was never checked against the chemistry of the residue itself.

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### 1.2 What this article finds

The residue never reaches the lumen as a residue (Section 4), so the gain takes a new and exact form that counts released chains and hydrolysed residues (Theorems 4.1, 4.2). Release is specific to the stop and failures become deletions (Section 5); the gain at the stop sets of the observed codes is far inside the existence condition (Section 6); the chain is faithful to its coding only when joining is nearly certain (Section 7) and the end of the read moves residues rather than particles (Section 8).

The conditions for a division are then stated (Section 12): the lipid condition confines fission to dusk, and nothing in the shape can mark dusk. What must withhold fission until then is a barrier, and no static barrier serves (Section 13). What withholds it is the photochrome (Section 14), whose timing comes from the forcing and whose energy is ample; what decides whether a given vessel divides is the extent of polypeptide its genome has made, and that condition filters the genome (Section 15). The genome is a tethered duplex, which supplies the gate's third input and shapes the vessel for its neck (Section 16). The lumen the new gain leaves is small, and what follows from its smallness, including the floor that bounds the gain from below, is set out in Section 17. Where this article's model departs from Articles 71–74, the departures are recorded in Appendix D and are not argued in the body.

### 1.3 What is established here, by kind

**Proved here.** The counting identity (Theorem 4.1); the gain and the founder (Theorem 4.2, Corollary 4.3); the three outcomes at the adjacent site (Lemma 5.1); the lipid condition (Theorem 12.3); that no shape or bulk threshold triggers (Proposition 12.5); that no static barrier holds and fires (Theorem 13.2); the read as the clock (Theorem 13.2); the exogenous timing (Theorem 14.2); the band and the filter (Theorems 15.5, 15.6); the exclusion of replication and fission (Theorem 16.3); the identity $E_{\mathrm{rod}} = E^{*}$ (Theorem 16.8); and the lumen invariant with the interior condition (Proposition 17.8, Theorem 17.10).

**Computed here.** The released chains per residue; the gain at three stop sets; the fidelity of released chains; the end-of-read term; the ledger; the barrier window and the drop required; the selected lengths and the share of genomes in the band. Appendix B.

**Supposed.** The sixteen hypotheses of Section 2.1, Section 14 and Section 15, with Hypothesis 13.1.

**Not claimed.** Everything in Section 3.

## 2 Status and hypotheses

**Convention 2.1** (Status labels)**.** [A] As in the coordinating paper. A statement marked *computed* is emitted by a block of Appendix B. Molecular readings carry [E] and enter no proof.

**Notation 2.2** (Symbols)**.** [A] As in Articles 72–74: $\lambda = \nu L/2$, $R_{62}$, $w_{62}$, $N_{\lambda} = w_{62}\lambda$, the gain $g$, the reduced volume $v$. A *word* is a codon of the strand as read. $s_0$ is the share of coded words that are stops; $a$ the probability that a sense word is accepted; $q$ the probability that an esterified residue joins the chain before its ester is hydrolysed; $\psi$ the probability of continuity at the end of a read; $z_c$ and $z_m$ the counterions accompanying a released chain and a free residue; $f_L$ the share of released chains entering the lumen. $P$ is the number of lumen particles added in a period, and

$$G = \iota_{\mathrm{eff}}/w_{62}$$

the residue-producing acceptances per lipid supplied, in units of the osmolyte per lipid of the taut closure vesicle. $\varrho$ is the number of chains released per residue-producing acceptance.

**Convention 2.3** (Independent words)**.** [A] Computed statements take the words of a read to be independent, each a stop with probability $s_0$. This is an illustration of the identities and not a model of any genome; a genome supplies $\varrho$ through its own sequence (Theorem 4.2).

### 2.1 The hypothesis register

**Hypothesis 2.4** (The orbit geometry)**.** [D] One strand per vessel, replication once per period and division only at dusk (Article 64 [Sch26j], Definition 5.3; Article 72, Lemma 6.1); a vessel born with $\lambda$ lipids reaches dusk with $2\lambda$ and divides symmetrically, into flaccid daughters below $v = 2^{-1/2}$ (Article 72, Definition 5.1). Registered as H1.

**Hypothesis 2.5** (The esterified residue)**.** [D] The residue formed at the C6$\alpha$–C5 attack on the 6,12-disubstituted chrysene has its carboxyl transferred to the 2′- or 3′-hydroxyl of the ribose of the adenosine tether complex from which it was excised, and is never free in the lumen while so bound. Registered as H2. [E] The ester to the adenosine 2′-oxygen is recorded in Article 57 [Sch26i], Section C.1, and the transfer to the 2′- or 3′-hydroxyl in Article 70 [Sch26b] and the filing [Sch25].

**Hypothesis 2.6** (Acceptance)**.** [D] A sense word is accepted with probability $a$, the class average of Article 71's $a(O)$ (its Hypothesis H5); an accepted sense word yields one esterified residue. A stop word always traps (Hypothesis 2.9). Registered as H3.

**Hypothesis 2.7** (Coupled supply)**.** [D] An esterified residue joins the chain arriving at its site with probability $q$; otherwise its ester is hydrolysed and the free residue enters the lumen. Registered as H4.

**Hypothesis 2.8** (The adjacent-occupant rule)**.** [D] The growing chain is esterified through its C-terminal residue to a tether ribose and is protected: its ester reacts only with the occupant of the adjacent site. Registered as H5. [E] The arrangement is that of a peptidyl ester on a carrier, the attacking amine belonging to the residue esterified at the next site.

**Hypothesis 2.9** (Release at the trapped stop)**.** [D] At a stop word a structure is formed and trapped and the carrier is consumed, as in Article 57, Proposition 7.9(b). The trapped structure causes scission of the tether phosphate on its chrysene side; the phosphate remains bound to its adenosine, moves only within the region of that site's $2'/3'$-OH, and cannot reach any other site. A chain transferred to that hydroxyl is hydrolysed at its terminal carboxyl and released. Registered as H6. [E] The phosphate acts on the transferred ester either as a nucleophile, through an acyl phosphate that is then hydrolysed, or by positioning water; the product, a C-terminal carboxyl, is the same.

**Hypothesis 2.10** (End-of-read continuity)**.** [D] A read is $W = \lfloor L/3 \rfloor$ words. A chain open when the read ends continues into the next read with probability $\psi$ and is otherwise stranded in the membrane. Registered as H7. [E] The poly-A tail is the candidate for continuity; $\psi$ is not supplied.

**Hypothesis 2.11** (Particles)**.** [D] Released chains and free residues are ideal solutes, accompanied by $z_c$ and $z_m$ counterions; a share $f_L$ of released chains enters the lumen and the rest remain in the membrane. Species equilibrated with the environment through the pore, among them the ammonium of Article 72, block Y7, exert no net osmotic pressure and are not counted [KK58]. Registered as H8.

**Hypothesis 2.12** (Delivery within the period)**.** [D] Every chain begun in a period is released, or stranded, within it. Registered as H9.

# 3 Non-implications

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

*(i)* That the vessel divides. *The gain fixes the reduced volume; the neck is not priced, and below the limit shape it carries the whole of the copy-number condition (Section 9).*

*(ii)* That any rate is known. *$a$, $q$, $\psi$, $z_c$, $z_m$ and $f_L$ are not supplied by the corpus. Figures at stated values illustrate the identities.*

*(iii)* That a genome has independent words. *Convention 2.3 is an illustration; the theorems hold for any sequence.*

*(iv)* That the phosphate chemistry is established. *Hypothesis 2.9 is a premise with a molecular reading, not a derivation.*

*(v)* That Article 57's conflict is settled. *Its Target 11.2 asks whether the limiting step at the non-releasing words is engagement or escape. This article supposes escape at the stop words and decides nothing about that question (Remark 5.4).*

*(vi)* That the orbit is viable. *The existence condition is met with a wide margin; whether a vessel so flaccid survives is Article 72's Target 11.7 and is open.*

*(vii)* That the released chain is the coded chain. *It is only when every sense word between two stops is accepted and joins (Section 7).*

*(viii)* That the gate is derived. *Hypotheses 14.1 and 15.1 are premises: that the photochrome holds fission while activated, and that the gate takes the extent of polypeptide as a second input, are supposed, and what reads the extent is not said.*

*(ix)* That the identities are exact for a single vessel. *The lumen holds of order fifty particles at the baseline, so they are statements about means (Remark 17.2).*

*(x)* That the anchors neck the vessel. *They bias the choice of shape and fix the axis; the neck is not priced here (Remark 16.12).*

*(xi)* That the genome is determined. *The band of Theorem 15.5 is bounded at one edge by a threshold the corpus does not supply; no unique genome follows.*

*(xii)* That any chronology is claimed. *As in Article 57, Section 3(iv).*

## 4 The residue does not enter the lumen

**Theorem 4.1** (The counting identity)**.** 🄳 *Under Hypotheses 2.5–2.11, the lumen particles added to a vessel in a period are*

$$P = (1 + z_c)\, f_L\, C + (1 + z_m)\, H,$$

*where $C$ is the number of chains released and $H$ the number of esterified residues hydrolysed before joining.*

*Proof.* A residue enters the lumen only if its ester is hydrolysed before it joins (H2, H4), which happens $H$ times. A joined residue leaves its chain only with the chain (H5), and a chain leaves its carrier only at a trapped stop (H6), once; a share $f_L$ of these enters the lumen (H8), $f_L C$ in all. The phosphate freed at a stop remains bound (H6). Stranded chains remain in the membrane (H7). Nothing else produced in the vessel reaches the lumen, and species equilibrated through the pore are not counted (H8). Each particle brings its counterions. □

**Theorem 4.2** (The gain without memory)**.** 🄳 *Under Hypotheses 2.4–2.12, the symmetric orbit of Article 72 has gain*

$$g = G\,\big[\,(1 + z_c)\, f_L\, \varrho + (1 + z_m)(1 - q)\,\big],$$

*and exists if and only if $g \le 1$. Here $\varrho$ is a property of the sequence read and of $a$, $q$ and $\psi$, and $G = \iota_{\mathrm{eff}}/w_{62}$.*

*Proof.* On the orbit a vessel is born with osmolyte $N_b$, adds $P$ in the period (H9), and halves at division: the fixed point is $N_b = P$. The residue-producing acceptances in a period number $\iota_{\mathrm{eff}}\lambda$, of which a share $1 - q$ is hydrolysed and which release $\varrho\,\iota_{\mathrm{eff}}\lambda$ chains; by Theorem 4.1, $P = \iota_{\mathrm{eff}}\lambda[(1 + z_c) f_L \varrho + (1 + z_m)(1 - q)]$. Dividing by $N_\lambda = w_{62}\lambda$ gives $g$. The existence condition is Article 72, Theorem 7.1, whose geometric part does not depend on how the osmolyte is supplied: at dusk $v = g\,2^{-1/2}$, and symmetric division into daughters of $\lambda$ lipids requires $v \le 2^{-1/2}$. □

**Corollary 4.3** (The founder)**.** 🄳 *Under the same hypotheses a founder born with no remnant and no chain has the same gain as the established lineage, and the founder condition coincides with the existence condition.*

*Proof.* Under H9 the particles of a period depend only on the period's acceptances, not on any stock carried from earlier periods; the remnant, which carried that memory in Article 72, no longer enters the osmolyte. □

## 5 The stop and its release

**Lemma 5.1** (Three outcomes at the adjacent site)**.** 🄳 *Under Hypotheses 2.6–2.9, a peptidyl ester whose adjacent site*

*(a) carries an esterified residue is attacked by its amine, and the chain, extended by one, is esterified at that site;*

*(b) carries a bare $2'/3'$-OH and no freed phosphate is transferred to that hydroxyl by transesterification, unextended;*

*(c) carries a bare $2'/3'$-OH and the freed phosphate of a trapped stop is transferred to that hydroxyl and hydrolysed, and the chain is released.*

*Case (b) arises at an unaccepted sense word and at a site whose residue was hydrolysed.*

*Proof.* H5 confines the ester's reaction to the occupant of the adjacent site. An accepted sense word whose residue has not hydrolysed presents an esterified residue (H3, H4); an unaccepted word, or one whose residue has hydrolysed, presents the bare ribose hydroxyl; a stop presents the bare hydroxyl with the freed phosphate within reach (H6). □

**Corollary 5.2** (Deletions, not strands)**.** 🄳 *Within a read no chain is stranded. A failure of acceptance or of supply removes one residue from the chain that passes it, and the chain continues; chains are stranded only at the end of a read (Hypothesis 2.10).*

**Proposition 5.3** (Specificity of release)**.** 🄳 *Under Hypothesis 2.9 release occurs at stop words and nowhere else. The freed phosphate adds no lumen particle.*

*Proof.* The phosphate is freed only by a trapped structure, which only a stop word produces (H6, Article 57, Proposition 7.9); it remains bound to its adenosine and reaches no other site. □

**Remark 5.4** (Article 57's Target 11.2)**.** 🄰 Hypothesis 2.9 places the stop words in mode (b) of Article 57's Proposition 7.9, the carrier consumed. That article records a

conflict with its companion [Sch26g], which finds engagement limiting at the non-releasing words, and leaves it open. The present article supposes mode (b) at the stop words for its own purposes. It does not resolve the conflict, and if mode (a) holds there the stop of this article has no carrier to consume and Hypothesis 2.9 fails.

**Scholium 5.5** (Which words stop)**.** The stop set depends on the mapping. Article 57, Proposition 10.13, finds two words, `UAA` and `UAG`, non-releasing in both observed mappings and three, `UGA`, `AGA` and `AGG`, whose behaviour the compartment decides. The fixed pair is two words of sixty-four; the standard set three; the mitochondrial set four. Section 6 carries all three.

# 6 The gain at the corpus stop sets

**Proposition 6.1** (Released chains per residue)**.** [D] *Computed, block T4. Under Convention 2.3 and an unbounded read,*

$$\varrho = \frac{s_0\, q}{s_0 + (1 - s_0)\, a\, q},$$

*which at $a = q = 1$ is $s_0$: two stops in succession release nothing. Against simulation over* 400,000 *words the closed form agrees to the printed precision or within sampling error at five settings; at the standard set with $a = q = 1$ the gain is* 0.0883*, at $q = 0.95$ it is* 0.1822*, and at $a = 0.8$, $q = 0.95$ it is* 0.2029*.*

*Proof.* Between two stops the words are sense words, each joining with probability $aq$; a stop releases a chain if and only if at least one residue joined since the preceding stop, which has probability $(1 - s_0)aq/(s_0 + (1 - s_0)aq)$. Stops occur $s_0/((1 - s_0)a)$ times per residue-producing acceptance. □

**Proposition 6.2** (The gain at three stop sets)**.** [D] *Computed, block T5, at $G = 1.8829$, $a = 1$, $f_L = 1$, $z_m = 0$:*

| *set* | $q$ | $z_c$=0 | $z_c$=1 | $z_c$=2 | *v dusk* |
|---|---|---|---|---|---|
| *fixed pair* | *1.00* | *0.0588* | *0.1177* | *0.1765* | *0.0416* |
| | *0.95* | *0.1529* | *0.2116* | *0.2704* | *0.1081* |
| | *0.90* | *0.2469* | *0.3056* | *0.3642* | *0.1746* |
| *standard* | *1.00* | *0.0883* | *0.1765* | *0.2648* | *0.0624* |
| | *0.95* | *0.1822* | *0.2702* | *0.3583* | *0.1288* |
| | *0.90* | *0.2761* | *0.3639* | *0.4517* | *0.1952* |
| *mito.* | *1.00* | *0.1177* | *0.2354* | *0.3530* | *0.0832* |
| | *0.95* | *0.2114* | *0.3287* | *0.4460* | *0.1495* |
| | *0.90* | *0.3052* | *0.4220* | *0.5389* | *0.2158* |

*The dusk reduced volume is given at $z_c = 0$. The hydrolysed residues alone contribute $G(1 - q)$:* 0.0188*,* 0.0941 *and* 0.1883 *at $q = 0.99$,* 0.95 *and* 0.90*.*

**Theorem 6.3** (The dichotomy)**.** [D] *Under Hypotheses 2.4–2.12 and Convention 2.3, at the three stop sets of Scholium 5.5, with $a = 1$, $f_L = 1$, $z_m = 0$, $q$ in* 0.90–1 *and $z_c$ in* 0–2*, the gain lies in* 0.0588–0.5389 *and the dusk reduced volume in* 0.0416–0.3811 *(block T5). Hence either a vessel in that range is viable, or the genome or the chemistry supplies more particles than these settings allow. At $a = q = 1$ and $z_c = 0$ a gain $g$ requires $s_0 = g/G$:* 0.5311 *for $g = 1$,* 0.4780 *for* 0.9*,* 0.3718 *for* 0.7*,* 0.2656 *for* 0.5*.*

*Proof.* Theorem 4.2 with Proposition 6.1; the range is taken over the table of Proposition 6.2, and $g$ is increasing in $s_0$, in $z_c$ and in $1 - q$ over it. □

**Remark 6.4** (Where the particles come from)**.** [A] At the standard set and $q = 0.95$ the hydrolysed residues supply 0.0941 of the gain 0.1822, as much as the released chains. Below a joining probability near one the vessel's osmolyte is set as much by the least controlled parameter as by the coded one. A statement that the stop frequency sets the shape of the vessel holds only as $q \to 1$.

**Scholium 6.5** (Environmental lipid now aggravates)**.** Article 74's shifted set point, $g_{\mathrm{eff}} = g_0(1 + F/\lambda)^{-3/2}$, holds for any osmolyte supply that carries no lipid, and therefore for Theorem 4.2. It was offered to bring a gain above one into the window. Applied to the gains of Proposition 6.2 it makes an already flaccid vessel more so. The remedy of Article 74, Section 6, is not needed and works in the wrong direction.

# 7 Fidelity of the released chain

**Proposition 7.1** (Deletions in released chains)**.** [D] *Computed, block T6. Under Convention 2.3, with $x = (1 - s_0)aq$, a chain is released with probability $1 - s_0/(1 - (1 - s_0)(1 - aq))$ at a stop, is faithful to its coding with probability $s_0 x/(1 - x)$, and carries $1 + (1 - s_0)aq/s_0$ joined residues on average. At the standard set:*

| $a$ | $q$ | mean length | faithful share |
|---|---|---|---|
| 1.0 | 1.00 | 21.33 | 1.0000 |
| 1.0 | 0.99 | 21.13 | 0.8231 |
| 1.0 | 0.95 | 20.32 | 0.4722 |
| 1.0 | 0.90 | 19.30 | 0.2982 |
| 0.8 | 0.99 | 17.10 | 0.1533 |

*Simulation over* 400,000 *words agrees to within sampling error.*

**Scholium 7.2** (What this costs the design)**.** The premise that the fate of a chain, membrane or lumen, follows from the kind of chain formed requires the chain formed to be the chain coded. At $a = 1$ and $q = 0.95$ fewer than half of released chains are faithful, and at $a = 0.8$, $q = 0.99$ fewer than a sixth. The product $aq$ is therefore a design parameter of the same standing as the stop frequency, and $f_L$ in Theorem 4.2 is a property of the chains made rather than of the chains coded.

## 8 The end of the read

**Proposition 8.1** (The end-of-read term)**.** [D] *Computed, block T4(b). Under Hypothesis 2.10 and Convention 2.3, with $y = (1 - s_0)(1 - aq)$ and a read of $W$ words, let $r_E$, $r_C$ be the chains released from a read starting empty or carrying an open chain and $e_E$, $e_C$ the chances it ends open; the stationary share of reads starting with a chain is $\pi_C = \psi e_E/(1 - \psi e_C + \psi e_E)$. At $L = 200$, $W = 66$, the standard set and $a = 1$:*

| $q$ | $\psi$ | chains/res. | stranded/res. | $g$ |
|---|---|---|---|---|
| 1.00 | 0.0 | 0.0462 | 0.0152 | 0.0869 |
| 1.00 | 0.5 | 0.0465 | 0.0076 | 0.0876 |
| 1.00 | 1.0 | 0.0469 | 0.0000 | 0.0883 |
| 0.95 | 0.0 | 0.0460 | 0.0151 | 0.1808 |
| 0.95 | 1.0 | 0.0468 | 0.0000 | 0.1822 |

*Simulation over* 40,000 *reads agrees to within sampling error.*

**Proposition 8.2** (Where the residues go)**.** [D] *Computed, block T4(b). At $\psi = 0$, $a = q = 1$, the residues carried into a stranded chain are $(1 - s_0)(1 - (1 - s_0)^W)/s_0$ per read, about* 20.33 *whatever the genome length, so the share of residues stranded falls with the read:*

| $L$ | $W$ | stranded/read | stranded share |
|---|---|---|---|
| 200 | 66 | 19.48 | 0.310 |
| 500 | 166 | 20.33 | 0.128 |
| 735 | 245 | 20.33 | 0.087 |
| 1000 | 333 | 20.33 | 0.064 |

*The chain term loses only* 0.015 *of its value at $L = 200$ and* 0.003 *at $L = 1000$.*

**Scholium 8.3** (The end of the read is a membrane question)**.** A chain stranded at the end of a read would, with continuity, have been released one read later; ending the read adds a stranded chain and removes almost no released one, which is why the gain barely moves. What moves is the destination of the residues. At $L = 200$ without continuity about three residues in ten end in the membrane, which enters Article 73's guest share and its existence bound [Sch26e] and not the osmolyte. The same short genomes that give the largest $G$ strand the most, so continuity is worth more to a short genome than to a long one.

## 9 The shape of a flaccid vessel

**Proposition 9.1** (The two-sphere floor)**.** [A] *Computed, block T2. Two spheres of radius ratio $\varrho$ with the area conserved have reduced volume $(1 + \varrho^3)/(1 + \varrho^2)^{3/2}$, which is minimal at $\varrho = 1$, where it is* 0.7071*: no two-sphere configuration has $v$ below $2^{-1/2}$.*

**Proposition 9.2** (The dusk gate overshoots)**.** [A] *Computed, block T2. On the orbit $v(t) = g/\sqrt{1 + t}$ with $t$ the elapsed share of the period, so $v$ crosses $2^{-1/2}$ at $t^* = 2g^2 - 1$ and the vessel spends $2(1 - g^2)$ of the period below the limit shape:* 0.195 *at $g = 0.95$,* 0.380 *at* 0.90*,* 0.555 *at* 0.85*. For $g < 2^{-1/2}$ the vessel is born below the limit shape and is never above it.*

## 10 The condensation law, retired

**Proposition 10.1** (What the first-order law would have required)**.** [D] *Computed, block T3. Under Article 71's Hypothesis H7 and Article 72, Theorem 7.1, $g = Gh(\kappa)$ with $h(\kappa) = (1 - e^{-\kappa})/(\kappa(2 - e^{-\kappa}))$ and $\kappa = cx^*$. At $G = 1.8829$ and $x^* = 0.0800$:*

| *target* | $\kappa$ | $c$ | $c/0.05$ |
|---|---|---|---|
| $g = 1.00$ | *0.571* | *7.13* | *143* |
| $g = 0.95$ | *0.633* | *7.91* | *158* |
| $g = 0.90$ | *0.701* | *8.76* | *175* |
| *founder (Art. 72, Thm. 7.5)* | *1.434* | *17.93* | *359* |

*At $g = 1$ the condensed share of throughput is $1 - 1/G = 0.4689$, a residue lifetime of 1.753 periods, 21.0 h, and $1.45 \times 10^{-5}$ condensations per site per second. The form $\phi = 1 - e^{-\kappa}$, which omits the halving at division, gives $\kappa = 0.633$ and is not the orbit's condensed share.*

**Remark 10.2** (The catalyst is not a single knob)**.** [A] Computed, block T3. Under that law $\iota_{\text{eff}} = \iota x^*/(x^* + K)$ and $\kappa = cx^*$ both rise with the catalyst density, and $\partial g/\partial x^*$ changes sign at $c = 2.04$: below it more catalyst raises the gain. At the corpus baseline, $c = 0.05$, the catalyst density moves the vessel away from division, not toward it. Reaching $\kappa = 0.571$ through $x^*$ at that $c$ would need some eleven catalyst units per lipid, against a 5.0% bilayer area share already at $x^* = 0.08$ and the leak of Article 64 a few per cent above it.

**Scholium 10.3** (Why the law is retired and not corrected)**.** The requirement above is not absurd: $c$ was never supplied by the corpus (Article 71, Non-implication (ii)), so a figure 143 times an illustrative constant is no contradiction, and a residue lifetime of a day is unremarkable. The law is retired because it describes the wrong chemistry. A free residue condensing with a bilayer remnant is not what Hypothesis 2.5 allows to happen, and the correct account needs no rate constant of that kind: what replaces $c$ is $q$, the ratio of joining to hydrolysis at one ester, which is dimensionless and checkable.

# 11 The ledger per period

**Proposition 11.1** (The ledger)**.** [D] *Computed, block T7. At $L = 200$ the residue-producing acceptances are 1,051.7 per period. Stops, chains released and free residues per period:*

| *set* | $q$ | *stops* | *chains* | *free res.* |
|---|---|---|---|---|
| *fixed pair* | *1.00* | *33.9* | *32.9* | *0.0* |
| *fixed pair* | *0.95* | *33.9* | *32.8* | *52.6* |
| *standard* | *1.00* | *51.7* | *49.3* | *0.0* |
| *standard* | *0.95* | *51.7* | *49.2* | *52.6* |
| *mito.* | *1.00* | *70.1* | *65.7* | *0.0* |
| *mito.* | *0.95* | *70.1* | *65.5* | *52.6* |

*At the standard set, $q = 1$ and $W = 66$, the chains stranded at the end of the read are 15.9 per period at $\psi = 0$, 8.0 at $\psi = 0.5$ and none at $\psi = 1$.*

**Remark 11.2** (What the ledger adds and does not)**.** [A] Each stop consumes one carrier (H6), which is a demand on Article 65's pool [Sch26f] not previously counted, at the rate of the stops column. The freed phosphate stays on its adenosine and is not a particle, so no phosphate is consumed. Stranded chains and membrane-retained chains enter Article 73's guest share, which is not recomputed here (Target 18.9).

# 12 What a successful division requires

The preceding sections fix the vessel's shape. They do not say when, or whether, it divides. This section states the conditions a period must satisfy for its division to succeed, and Section 13 prices the one of them the corpus has not supplied.

**Definition 12.1** (A successful period)**.** [D] A period divides successfully when

(D1) *the orbit exists*: $g \le 1$, so that the dusk reduced volume does not exceed $2^{-1/2}$ and two daughters of $\lambda$ lipids are available (Article 72, Theorem 7.1);

(D2) *the daughters are enclosures*: each receives at least $\lambda$ lipids, enough to close one minimal anchored enclosure (Article 72, Proposition 4.1);

(D3) *each daughter holds a strand*: replication has completed and the two tethered footprints have segregated before fission (Article 64, condition C3; Article 74, Scholium 7.3);

(D4) *exactly one fission occurs, and at dusk*: no earlier event, and no partition into more than two.

**Proposition 12.2** (Within the period)**.** [A] *Computed, block T8. On the orbit the lipids and the osmolyte grow in proportion within a period, $\Lambda(t) = \lambda(1 + t)$ and $N(t) = gN_\lambda(1 + t)$ with $t$ the elapsed share, so*

$$v(t) = \frac{g}{\sqrt{1 + t}},$$

*strictly decreasing from $g$ at birth to $g\,2^{-1/2}$ at dusk.*

**Theorem 12.3** (The lipid condition confines fission to dusk)**.** [D] *Computed, block T8. Symmetric fission at time $t$ gives*

*daughters of $\lambda(1+t)/2$ lipids, which meets (D2) if and only if $t = 1$. A tolerance $\theta$, admitting $t \in [1-\theta, 1]$, costs each daughter a shortfall of $\theta/2$ in lipids.*

*Proof.* $(1+t)/2 \geq 1$ iff $t \geq 1$, and $t \leq 1$ within the period. □

**Corollary 12.4** (Geometry gates nothing)**.** [D] *Under Theorem 6.3 the gain does not reach $2^{-1/2}$, so by Proposition 9.2 the vessel satisfies the geometric condition for fission from birth. Condition (D4) is therefore not supplied by the shape: between birth and dusk the vessel is permitted to divide and must not.*

**Proposition 12.5** (Shape is not an independent trigger)**.** [A] *Computed, block T9. Since $v(t)$ is strictly decreasing (Proposition 12.2), a threshold $v_{\text{fire}}$ fires at a definite time, and at dusk if and only if $v_{\text{fire}} = g\,2^{-1/2}$. Such a threshold is tuned to the gain and carries no information the gain does not already fix. The same holds for any quantity monotone within the period, the free remnant per lipid among them, which Article 72, Theorem 7.1, fixes at $gw_{62}$ at every division.*

**Scholium 12.6** (Neither bulk nor shape)**.** The two readings that suggest themselves both fail for the same reason. A bulk concentration is fixed by the orbit and repeats every period; a shape threshold is a clock only when set to a value the gain determines. Each would divide the vessel at dusk, and each would have to be tuned to do it. What (D4) asks for is something that distinguishes dusk without being told where dusk is, and the cycle has exactly one such thing already: the forcing itself, and the completion of replication that Article 64, Theorem 8.2, places within the light phase.

**Proposition 12.7** (The replication interval)**.** [D] *Computed, block T8. With Article 64's clock, a strand of $L$ units at $t_{\text{add}}$ seconds per unit occupies $t_{\text{rep}} = L\,t_{\text{add}}$ of the period $T = 43{,}200$ s:*

| $L$ | $t_{\text{add}}$ | $t_{\text{rep}}$ (s) | share of $T$ | $(T - t_{\text{rep}})/t_{\text{rep}}$ |
|---|---|---|---|---|
| 200 | 30 | 6000 | 0.139 | 6.20 |
| 200 | 60 | 12000 | 0.278 | 2.60 |
| 200 | 100 | 20000 | 0.463 | 1.16 |
| 735 | 30 | 22050 | 0.510 | 0.96 |
| 735 | 60 | 44100 | 1.021 | — |

*At $L = 735$ and $t_{\text{add}} = 60$ s replication does not finish within the period and no division of that period can satisfy (D3). Condition (D3) is therefore the clock cap of Article 72, block Y8, read as a condition on division rather than on the genome.*

# 13 The brake

Conditions (D1)–(D3) are met by the orbit, by the lipid condition and by the clock. Condition (D4) is not met by anything the corpus supplies: the vessel is permitted to divide from birth and must be prevented until dusk. What prevents it can only be a barrier at the neck. This section asks what such a barrier must do, and finds that the answer does not depend on its height.

**Hypothesis 13.1** (Escape over a barrier)**.** [D] Fission is an escape over a barrier $B$, occurring as a Poisson process of rate $k = \nu\, e^{-B/k_B T}$ with $\nu$ an attempt rate. External; $\nu$ is not supplied by the corpus and no value is assumed below except where stated. Registered as H10.

**Theorem 13.2** (No static barrier holds and fires)**.** [D] *Computed, block T9. Require that the expected number of fission events while the barrier must hold, over a time $t_h$, be at most $\varepsilon$, and that fission occur with probability at least $1-\delta$ within a firing window $t_f$. Then*

$$B \geq k_B T \ln \frac{\nu t_h}{\varepsilon}, \qquad B \leq k_B T \ln \frac{\nu t_f}{\ln(1/\delta)},$$

*and a single $B$ meets both if and only if*

$$\frac{t_f}{t_h} \geq \frac{\ln(1/\delta)}{\varepsilon},$$

*a condition in which neither $\nu$ nor $B$ appears. Under Theorem 12.3, with a tolerance $\theta$ about dusk, $t_h = (1-\theta)T$ and $t_f = \theta T$, so $t_f/t_h = \theta/(1-\theta)$, which is at most one. The requirement is at least 23.0 at $\varepsilon = \delta = 0.10$ and 460.5 at 0.01. No static barrier satisfies both.*

*Proof.* For a Poisson process of rate $k$ the expected events in $t_h$ are $kt_h \leq \varepsilon$ and the probability of at least one in $t_f$ is $1 - e^{-kt_f} \geq 1-\delta$, that is $kt_f \geq \ln(1/\delta)$. Dividing eliminates $k$, hence $\nu$ and $B$. □

**Corollary 13.3** (What the brake must supply)**.** [D] *Computed, block T9. The barrier must fall at dusk by at least*

$$\Delta B = k_B T \ln\left[\frac{\ln(1/\delta)}{\varepsilon} \cdot \frac{1-\theta}{\theta}\right],$$

*again independent of $\nu$:*

| $\theta$ | $\Delta B$ *at* 0.01 | *at* 0.05 |
|---|---|---|
| *0.50* | *6.13* | *4.09* |
| *0.25* | *7.23* | *5.19* |
| *0.10* | *8.33* | *6.29* |
| *0.05* | *9.08* | *7.04* |
| *0.01* | *10.73* | *8.69* |

*in units of $k_BT$, at $\varepsilon = \delta$ as marked.*

**Proposition 13.4** (The absolute height)**.** [D] *Computed, block T9. Given an attempt rate, the holding requirement at $\varepsilon = 0.01$ over a whole period is* 29.1, 36.0 *and* 42.9 $k_BT$ *at $\nu = 10^6$, $10^9$ and $10^{12}\,\mathrm{s}^{-1}$. These are the heights the barrier must have between births; the firing requirement is the same barrier lowered by Corollary 13.3.*

**Scholium 13.5** (The device that is wanted)**.** Article 73 asked for a drive and Article 74 for a curvature switch, and both were priced against the whole bending cost of fission: Article 73's line tension fell short by factors of 1.3 to 5.6 under its strictest criterion, and the photochrome delivered a fractional area difference of 0.012 to 0.031 against the 0.066 its office required, short by between two and five. What Corollary 13.3 asks for is of a different order: a few $k_BT$, applied once per period, at one place.

The reversal is the point. A vessel at the gains of Section 6 does not need to be pushed into a dividing shape; it is in one from birth. What it needs is to be held out of fission while it replicates, and released when the replication is done. The photochrome, which failed as a bulk curvature device, is not asked for bulk curvature here, and the two offices it already holds, the gate on expression and the timing of the tether, are both tied to the forcing that defines dusk. Whether it can shift a neck barrier by a few $k_BT$ is not computed here and is Target 13.8.

**Remark 13.6** (What the theorem does not say)**.** [A] Theorem 13.2 says that a barrier of fixed height cannot serve, not that a barrier exists, nor what its height is, nor that the neck is the place where it sits. H10 treats fission as a single escape over a single barrier, which a molecular treatment may not support: the passage has intermediates, and a hemifission state with its own lifetime would replace the two-state estimate with a sequence. The result that survives such a replacement is the comparison of timescales, since the hold and the fire are separated by the ratio $\theta/(1-\theta)$ whatever the path.

**Proposition 13.7** (The conditions, assembled)**.** [D] *Subject to Appendix A and H10, a period divides successfully if and only if*

*(D1)* $g \le 1$*, which Theorem 6.3 gives with a wide margin at the stop sets considered;*

*(D2) fission occurs at dusk within a tolerance $\theta$, which Theorem 12.3 shows is what (D2) means;*

*(D3)* $L\,t_{\mathrm{add}} \le T$*, with the segregation of the two footprints complete (Proposition 12.7);*

*(D4) the neck barrier holds through $(1-\theta)T$ and falls by at least $\Delta B$ of Corollary 13.3 at dusk.*

*Of these the corpus supplies the first three. The fourth is supplied by nothing, and is the whole of what stands between the cycle and a proof that it divides.*

**Target 13.8** (The switch at the neck)**.** Determine whether a photochrome switching at dusk, or the completion of replication, lowers a neck barrier by the few $k_BT$ of Corollary 13.3, and at what place on the vessel. Inherits Target 18.2 and makes it quantitative.

## 14 The photochrome as the brake

Condition (D4) asks for something that withholds fission until dusk and then permits it. Section 12 found that nothing within the vessel can mark dusk: the shape and every bulk concentration are slaved to the gain, and a threshold on either must be told where dusk is. The cycle has one thing that is not within the vessel.

**Hypothesis 14.1** (The switch)**.** [D] The photochrome is a substituted *trans*-azobenzene derived from the 6,12-disubstituted chrysene and carried in the bilayer. It is activated by the forcing and relaxes when the forcing ends. In the activated state it holds fission; de-activated, it permits it. Two conditions on the molecule are carried with it: the thermal lifetime of the activated form is short against the firing window $\theta T$, which is about 1.2 h at $\theta = 0.10$, so that the brake falls at dusk; and the photostationary state under the forcing is biased to the activated form, so that the brake holds through the day. Registered as H11. [E] The connector population and its per-molecule area change are those of Article 64, Proposition 9.6, and Article 74, block U5.

**Theorem 14.2** (The timing is exogenous)**.** [D] *Under H11 the brake falls when the forcing ends, which is dusk by*

*Article 64, Definition 5.3. The firing time is therefore set outside the vessel and is not a threshold on any internal quantity: it requires no tuning, is the same for every lineage and every genome, and is immune to Proposition 12.5.*

**Corollary 14.3** (The dusk gate acquires a mechanism)**.** [D] *Article 64 carries division at dusk as a definition and Article 72 as a hypothesis. Under H11 it is a consequence: the vessel divides at dusk because that is when the brake is released.*

**Proposition 14.4** (What the brake must supply, and what it has)**.** [D] *Computed, block T11. Theorem 13.2 requires a fall of* 4.09 *to* 10.73 $k_BT$ *over the tolerances considered. With the admissible connector population all switched, Article 74, block U5, gives a fractional outer-leaflet area excess* $\delta_a = 0.012$ *at* $dA = 0.10$ $nm^2$ *and* 0.031 *at* 0.25 $nm^2$*; in the bilayer-couple picture* $C_0 = \delta_a/d$ *and the bending energy of a closed vessel shifts by* $\Delta E = 8\pi\kappa[1 - (1 - \delta_a R/2d)^2]$*:*

| $L$ | $R$ (nm) | $\delta_a$ | $\kappa$=10 | $\kappa$=20 |
|---|---|---|---|---|
| 200 | 13.82 | 0.012 | 10.3 | 20.6 |
| 200 | 13.82 | 0.031 | 26.2 | 52.4 |
| 500 | 22.15 | 0.012 | 16.4 | 32.8 |
| 735 | 27.07 | 0.012 | 20.0 | 40.0 |
| 1000 | 31.80 | 0.012 | 23.4 | 46.8 |

*in* $k_BT$*, with* $R$ *the birth radius with guests (Article 73, block Z1). Every entry exceeds the requirement at the strictest tolerance. The two quantities are not the same quantity:* $\Delta E$ *is a difference between two equilibrium configurations and* $\Delta B$ *a difference of barriers, and the comparison establishes that the switch commands energy of the required order with an order of magnitude of headroom, not that it supplies the drop (Remark 14.6).*

**Scholium 14.5** (Why the same device suffices here and not there)**.** Article 74 asked the photochrome to drive the vessel into a dividing shape and found it short by between four and fifty times. The office asked of it here is different in kind. A driver must change the shape and is priced against the whole bending energy; a brake must only shift the energy of one configuration against another, and is priced against the difference. The population the corpus admits is ample for the second and not for the first, and the numbers in both calculations are the same numbers.

**Remark 14.6** (What is bounded and what is not)**.** [A] $\Delta E$ is the difference in whole-vessel bending energy between the two states of the switch. It bounds the energy the switch commands; it does not say that the difference is applied where fission passes, nor that the barrier of Hypothesis 13.1 is the quantity shifted. What the calculation establishes is that the device is not short of energy, which is what Article 74 found it to be in its other office (Target 13.8).

## 15 The genome that selects itself

The brake supplies the timing and nothing else: released at every dusk, it would divide every vessel, whatever its genome. What decides whether a given vessel divides is the second input to the gate, and that input is the extent of polypeptide the genome has made.

**Hypothesis 15.1** (The gate has two inputs)**.** [D] Fission is permitted when the photochrome is de-activated *and* the extent of membrane-retained polypeptide is at or above a threshold $C_{\mathrm{fire}}$. Registered as H12. [E] The extent is read where the chains are made, in the bilayer, and not in the lumen.

**Proposition 15.2** (The extent is a level the genome fixes)**.** [D] *Computed, block T10(a). Membrane-retained chains accumulate at a constant rate within the period,* $P(t) = P_b + C\lambda t$ *with* $C = (1 - f_L)\,\varrho\,\iota_{\mathrm{eff}}$*, against* $\Lambda(t) = \lambda(1 + t)$*. Symmetric division halves* $P$ *and* $\Lambda$ *alike, so the per-lipid extent is preserved at division and its fixed point satisfies* $p_b = (p_b + C)/2$*, that is* $p(t) = C$ *for every* $t$*. The extent therefore sits at a constant level, the same at every dusk, determined by the genome through* $\varrho$ *and by the chemistry through* $f_L$ *and* $\iota_{\mathrm{eff}}$*.*

**Scholium 15.3** (Constancy is what makes it readable)**.** Proposition 15.2 would be fatal to a gate that had to supply its own timing: a quantity constant across the period marks no moment in it. With the timing supplied from outside, constancy is the property wanted. The level is stable, it is reached within the first periods of a lineage, and the comparison against $C_{\mathrm{fire}}$ gives the same verdict at every dusk, so a genome that divides once divides always and one that does not never does.

**Proposition 15.4** (Expression sets the level)**.** [D] *Computed, block T12. At* $a = q = 1$ *and* $\iota_{\mathrm{eff}} = 0.1600$*,* $\varrho = s_0$ *and* $C = (1 - f_L)s_0\iota_{\mathrm{eff}}$*, in units of* $10^{-3}$ *per lipid:*

| $s_0$ | $1 - f_L = 0.25$ | 0.50 | 0.75 |
|---|---|---|---|
| *0.0156* | *0.625* | *1.250* | *1.875* |
| *0.0312* | *1.250* | *2.500* | *3.750* |
| *0.0469* | *1.875* | *3.750* | *5.625* |
| *0.0625* | *2.500* | *5.000* | *7.500* |
| *0.0938* | *3.750* | *7.500* | *11.250* |

*A threshold on the extent is therefore a threshold on the stop density: the genome must express often enough, and retain enough of what it expresses, to hold the gate open. In absolute terms the read completes $n_{\text{stop}} = s_0 L/3$ chains, which depends on the length as well.*

**Theorem 15.5** (The band)**.** [D] *Computed, block T12. Three conditions bound the genome:*

$$\begin{aligned} \textit{expression:} \quad & C \geq C_{\text{fire}} \implies s_0 \geq s_0^{\text{fire}}, \\ \textit{the clock (D3):} \quad & L\, t_{\text{add}} \leq \delta T \implies L \leq L_{\max}, \\ \textit{the floor:} \quad & R_{62}(L) \geq R_c \implies L \geq L_{\min}. \end{aligned}$$

*With $L_{\min} = 118$ and 169 from the packing floor of Article 73, block Z2, at $R_c = 10.0$ and 12.0 nm:*

| $t_{\text{add}}$ | $\delta$ | $L_{\min}$ | $L_{\max}$ | *width* | $n_{\text{stop}}$ *at* $s_0 = 3/64$ |
|---|---|---|---|---|---|
| *30* | *1.00* | *118* | *1440* | *12.20* | *1.8–22.5* |
| *30* | *0.50* | *118* | *720* | *6.10* | *1.8–11.2* |
| *60* | *1.00* | *118* | *720* | *6.10* | *1.8–11.2* |
| *60* | *1.00* | *169* | *720* | *4.26* | *2.6–11.2* |
| *100* | *1.00* | *118* | *432* | *3.66* | *1.8–6.8* |
| *100* | *0.50* | *169* | *216* | *1.28* | *2.6–3.4* |

*The band is a region in the genome's length and its expression density, and is non-empty over the whole range of rates the corpus carries.*

**Theorem 15.6** (Three heritable ways to fail)**.** [D] *Computed, block T12. A genome fails to propagate when*

*(F1) it is too stop-poor, or retains too little of what it expresses: $C < C_{\text{fire}}$, the gate never opens at any dusk, and the vessel does not divide;*

*(F2) it is shorter than $L_{\min}$: its enclosure is below the packing floor;*

*(F3) it is longer than $L_{\max}$: replication is unfinished when the forcing ends, and (D3) fails.*

*Each is a property of the sequence and is inherited. None is a property of a rate: $t_{\text{add}}$, $\delta$, $\iota_{\text{eff}}$ and $f_L$ are common to a lineage, and what distinguishes one genome from another is its length and the frequency of its stops.*

**Corollary 15.7** (Self-filtering)**.** [D] *A genome not rich enough in expression does not divide, and its lineage ends with it, no vessel being lost and no daughter miscarried: it simply grows and does not divide. A genome inside the band divides at every dusk, and its daughters carry the same sequence, the same level and the same verdict. The condition for propagation is tested by the cycle at every period, and nothing tests it.*

**Proposition 15.8** (The gain over the band)**.** [D] *Computed, block T12. At the standard stop set with $a = q = 1$, $f_L = 1$, $z_c = 0$:*

| $L$ | $G$ | $g$ | $v$ *at dusk* |
|---|---|---|---|
| *118* | *2.4513* | *0.1149* | *0.0812* |
| *200* | *1.8829* | *0.0883* | *0.0624* |
| *432* | *1.2811* | *0.0601* | *0.0425* |
| *720* | *0.9924* | *0.0465* | *0.0329* |
| *1440* | *0.7017* | *0.0329* | *0.0233* |

*Every genome in the band satisfies the existence condition $g \leq 1$, and by Corollary 17.11 none of these entries satisfies the interior condition: at $z_c = 0$ they lie below the floor at every length, and are to be read with $z_c \geq 1$ (Scholium 17.14).*

**Scholium 15.9** (What the cycle has become)**.** Read forward, the model is this. One strand is read once per period. Each accepted word puts a residue on its own tether ribose; the residue joins the chain arriving from the preceding site; at a stop the chain is taken onto the stop site's hydroxyl and hydrolysed off it. Some of the chains leave for the lumen and give the vessel its osmolyte and therefore its shape; the rest stay in the bilayer and are what the gate reads. While the forcing runs, the photochrome holds fission and the strand is copied. When the forcing ends the brake falls, and the vessel divides if, and only if, its own expression has held the gate's second input open. By then both strands exist and their footprints have segregated, and the vessel holds twice its birth lipids, so each daughter closes an enclosure. The genome sets its own shape by how many of its chains leave, its own permission by how often it stops, and its own admissibility by its length. What divides the vessel is the end of the day; what decides whether it is divided is the genome.

**Remark 15.10** (Where this is weaker than it reads)**.** [A] Three joints bear naming. H12 is new to the corpus: that the gate takes the extent as a second input is supposed, not derived, and what reads the extent is not said. $C_{\text{fire}}$ is

likewise unsupplied, so the expression edge of the band in Theorem 15.5 is a form and not a number; what is computed is how the level depends on the genome, not where the threshold sits. And the gain over the band is now bounded below as well as above (Corollary 17.11), by a floor that is imported and whose binding form is not settled (Remark 17.15): the vessel's shape at low reduced volume remains uncomputed, and Theorem 17.10 is necessary and may be far from sufficient.

# 16 The tethered duplex

The gate has so far two inputs, one exogenous and one from expression. This section supplies the third, from the genome's own material: a vessel divides only when it carries two complete duplexes, and the anchors that hold them are what shapes the vessel for the neck.

**Hypothesis 16.1** (The duplex)**.** [D] The genome is a duplex, both of whose strands are tethered into the bilayer at their anchors. The strands separate within the period; each templates its complement, which is tethered as it is nucleated, so replication yields two complete duplexes. Registered as H13. [E] The tether is the nucleotide–chrysene unit of Article 62, inserting at nucleation as Article 74, Hypothesis H4, supposes.

**Hypothesis 16.2** (Separation needs the switch)**.** [D] Strand separation requires the photochrome in its activated state, and ceases when the forcing ends. Registered as H14. [E] This is the local opening Article 64, Theorem 8.2, places in the light phase.

**Theorem 16.3** (Replication and fission are mutually exclusive)**.** [D] *Under H11 and H14 the photochrome holds fission in exactly the state in which it permits separation, and permits fission in exactly the state in which separation has ceased. No fission therefore occurs while replication is in progress.*

*Proof.* H11 makes the activated state the holding state; H14 makes it the separating state. The two states are complementary, so the permitting state is the non-separating one. □

**Remark 16.4** (The exclusion does not supply the clock)**.** [A] Theorem 16.3 orders replication and fission; it does not bound the replication interval. The switch de-activates when the forcing ends whether or not the strand is finished, so a vessel with $L\,t_{\mathrm{add}} > \delta T$ reaches dusk with one duplex and a partial strand and the brake falls on schedule. Condition (D3) therefore survives as a separate requirement and is the upper edge of the band in Theorem 15.5; what the exclusion removes is the possibility of a fission interrupting a replication, not the possibility of a replication unfinished at dusk.

**Corollary 16.5** (The third input)**.** [D] *A vessel that has not completed replication at dusk carries one duplex and a partial strand. Fission then gives one daughter a duplex and the other less than one, and the second is lost (Article 72, Lemma 6.1). The requirement of two complete duplexes is therefore the third input to the gate, and it is enforced by the material rather than stipulated.*

**Proposition 16.6** (The anchor count doubles)**.** [D] *Computed, block T13. With both strands of each duplex tethered, the dusk vessel carries* $4L$ *anchors at one tether per base where Article 73, block Z1, counted* $2L$*. The guest share and the existence bound* $g \le (1+\phi)^{3/2}$ *become*

| $L$ | *guests* | $\phi$ *(Z1)* | $\phi$ *new* | *bound* |
|---|---|---|---|---|
| *200* | *2987* | *0.1241* | *0.1433* | *1.223* |
| *500* | *9063* | *0.1547* | *0.1739* | *1.272* |
| *735* | *14693* | *0.1726* | *0.1918* | *1.301* |
| *1000* | *21767* | *0.1897* | *0.2089* | *1.329* |

*The bound is not binding: the gains of Proposition 15.8 are below* 0.12 *against a bound above* 1.22*.*

**Remark 16.7** (The guest share is corrected three ways and consolidated in none)**.** [A] Proposition 16.6 alters $\phi$ for the anchors alone. Two further corrections are owed: the co-aggregate of Article 73 is removed with Article 71's Hypothesis H8 (Appendix D), and the membrane-retained and stranded chains of Sections 8 and 11 are new guests not counted there. The figure 0.1433 is therefore partial and is not this article's value for the guest share, which is Target 18.9. The computation is also at one tether per base; at the ledger's $5L$ the anchors would be $20L$ and $\phi$ substantially larger, so Article 74's Target 10.7 is not discharged here.

**Theorem 16.8** (The anchored duplex pays exactly the bending tolerance)**.** [A] *Computed, block T13. A rod of contour* $C$ *and persistence length* $L_p$ *held to a curvature radius* $R$ *costs* $(L_p/2)\,C/R^2$ *in* $k_BT$*. With* $C = Lh$ *and Article 62's*

$R_{62}^2 = L_p hL/(2E^*)$,

$$E_{\mathrm{rod}} = \frac{L_p\, Lh}{2R_{62}^2} = E^*,$$

*exactly, and independently of the genome length. The bending tolerance Article 62 stipulates is the price the anchored duplex pays on its own minimal enclosure.*

**Proposition 16.9** (What flattening is worth)**.** [D] *Computed, block T13. On a region of curvature radius $R$ the rod pays $E^*(R_{62}/R)^2$ and so gains $E^*[1-(R_{62}/R)^2]$ by lying on a flatter one, up to $E^*$ when straight:* 3.06, 5.56 *and* 7.50 $k_BT$ *at $R/R_{62} =$* 1.2, 1.5 *and* 2.0 *with $E^* =$* 10*. Two duplexes, one at each pole, command up to $2E^*$, which is* 6, 20 *and* 60 $k_BT$ *over the stipulated range $E^* =$* 3, 10, 30*.*

**Scholium 16.10** (How the anchors shape the vessel)**.** A vessel at the gains of Proposition 15.8 has far more area than its volume requires and must adopt some shape of low reduced volume; which one is not settled by the corpus (Target 18.1). The anchors enter there. Each duplex is a stiff rod which pays $E^*$ on a sphere of its own closure radius and less on anything flatter, so a rod flattens the region it occupies; two rods, demixed to opposite poles by Article 74, Hypothesis H5, flatten the two poles and leave the curvature to be taken up between them. The shape they favour is the one with its curvature at the equator, which is the shape with a neck. The energy they bring to that choice is $2E^*$, 6–60 $k_BT$, against branch differences the corpus has not computed: the selection is conditional on those differences being the smaller, and is stated as such. It is conditional in a second way. By Theorem 16.8 the anchors command exactly what Article 62 stipulates and no more, so the budget is a stipulation and not a measurement, and its range is a factor of ten. As Article 71's remark on $\nu$ says of its periods, every figure here carries that stipulation.

**Proposition 16.11** (The domains are patches)**.** [D] *Computed, block T13. Two tethered domains of area share $s$ each, set at opposite poles, are caps of half-angle* $\arccos(1-2s)$*, and the band of bulk lipid between them spans* $180^\circ - 2\arccos(1-2s)$*:*

| $s$ | cap half-angle | band |
|---|---|---|
| 0.05 | 25.8 | 128.3 |
| 0.10 | 36.9 | 106.3 |
| 0.20 | 53.1 | 73.7 |
| 0.25 | 60.0 | 60.0 |
| 0.50 | 90.0 | 0.0 |

*in degrees. Article 74, block U4, puts one strand's tethers at* 0.010 *to* 0.048 *of the bilayer and all guests together near a tenth, so the caps are small and the band is wide. The duplexes do not tile the vessel and do not close the neck; what they fix is the axis and the assignment of one duplex to each daughter.*

**Remark 16.12** (What the anchors do not do)**.** [A] Theorem 16.8 is an identity about a rod on a sphere, not a shape calculation: it gives the energy the anchors bring to the choice of branch and not the branch. Proposition 16.11 bounds what the domains can close, and they close nothing. The neck itself remains unpriced, as it has been since Article 73 (Target 18.2), and the claim here is the weaker one that the anchors bias the vessel toward a necked shape and fix the axis along which it necks.

# 17 The small lumen, and what else is in it

The gain of Theorem 4.2 makes the lumen small. Three things follow that would not have arisen at Article 72's larger osmolyte, and they are set out here rather than left to the reader.

**Proposition 17.1** (How many particles)**.** [D] *Computed, block T14(a). At the gains of Proposition 15.8 the osmolyte at birth is*

| $L$ | $N_\lambda$ | $g$ | $gN_\lambda$ | $N^{-1/2}$ |
|---|---|---|---|---|
| 200 | 558.6 | 0.0883 | 49.3 | 14.2% |
| 432 | 1773.2 | 0.0601 | 106.5 | 9.7% |
| 720 | 3815.3 | 0.0465 | 177.5 | 7.5% |

*The vessel's shape is set by of order fifty particles at the baseline, whose Poisson spread is* 14%*, and division partitions them with the same spread.*

**Remark 17.2** (The identities are statements about means)**.** [A] The reduced volume, the orbit and the gate's comparison are all treated as deterministic above. At the counts of Proposition 17.1 they are not. The existence condition survives, being met by a margin of an order of magnitude against a spread of a seventh; the comparison in Hypothesis 15.1 does not survive as sharply, and Corollary 15.7 should be read as a statement about a genome's expected verdict and not about every period of every vessel.

**Hypothesis 17.3** (The counterion of the strand)**.** [D] The counterion balancing the genome's charge is the ammonium the pore supplies (Article 72, block Y7). It is therefore equilibrated with the environment, the strand's charge is balanced by a Donnan potential rather than by excess particles, and Hypothesis 2.11 excludes it from the count. Registered as H15.

**Proposition 17.4** (What the strand would add if H15 fails)**.** [D] *Computed, block T14(b). Replication adds* $2L$ *nucleotides per period. If a fraction* $f_M$ *of their counterions were osmotically free and impermeant, the period would gain* $f_M\,2L$ *particles and the gain would rise by* $f_M\,2L/N_A$*:*

| $L$ | $f_M$ | *particles* | *added to g* | *g total* |
|---|---|---|---|---|
| 200 | 0.20 | 80.0 | 0.1432 | 0.2315 |
| 200 | 0.24 | 96.0 | 0.1719 | 0.2601 |
| 200 | 0.30 | 120.0 | 0.2148 | 0.3031 |
| 432 | 0.24 | 207.4 | 0.1169 | 0.1770 |
| 720 | 0.24 | 345.6 | 0.0906 | 0.1371 |

*The term is about* 1.9 *times the chain term at every length and would dominate the gain.*

**Corollary 17.5** (The existence condition is robust to it)**.** [D] *Every total in Proposition 17.4 is below* 0.31 *against the bound* $g \le 1$*, so the orbit exists and the vessel is flaccid throughout the period whether H15 holds or fails. What the term changes is the value of the gain and not any conclusion of Section 15 or Section 14.*

**Proposition 17.6** (A vessel that never divides)**.** [D] *Computed, block T14(c). Lipids accumulate without reset, so* $v = g/\sqrt{1+n}$ *after* $n$ *periods:* $0.707g$*,* $0.500g$*,* $0.354g$ *and* $0.258g$ *at* $n = 1, 3, 7$ *and* 14*. A vessel at* $g = 0.09$ *reaches* $v = 0.0232$ *within fourteen periods. Quiescence is not a steady state, and what becomes of such a vessel is not determined here (Target 18.5).*

**Proposition 17.7** (The founder's extent)**.** [D] *Computed, block T14(d). From an empty start the per-lipid extent approaches its fixed point as* $1 - 2^{-n}$*, so a threshold at a fraction* $m$ *of* $C$ *is first passed at period* $\lceil -\log_2(1-m) \rceil$*:* 1, 2, 4, 5 *and* 7 *at* $m = 0.50, 0.75, 0.90, 0.95$ *and* 0.99*. A founder cannot divide before then, and by Proposition 17.6 it deflates while it waits. The threshold's margin below* $C$ *is therefore a founder condition, and Corollary 4.3, which withdraws Article 72's founder bound for the osmolyte, does not extend to the extent.*

## 17.1 The interior

The three preceding statements concern how few particles the lumen holds. This one concerns whether there is a lumen at all, and it bounds the gain from below for the first time in the arc.

**Proposition 17.8** (The lumen invariant)**.** [A] *Computed, block T15(a). For a closed vessel of area* $A$ *and volume* $V$ *the characteristic half-thickness of the lumen is* $3V/A$*, which at reduced volume* $v$ *on a vessel of area-equivalent radius* $R$ *is* $vR$*. On the orbit* $v = g$ *at birth,* $R = R_{62}$*, and* $g = \iota_{\mathrm{eff}} P / w_{62}$ *with* $P$ *the lumen particles per residue-producing acceptance, so, since* $w_{62} = u_0 R_{62}/R_0$*,*

$$\frac{3V}{A} \;=\; g\,R_{62} \;=\; \frac{R_0}{u_0}\,\iota_{\mathrm{eff}}\,P \;=\; 153.44\ nm \times \iota_{\mathrm{eff}} P.$$

*The closure radius cancels, so the thickness is the same at every genome length; and* $v$ *falls by* $2^{-1/2}$ *within the period while* $R$ *rises by* $2^{1/2}$*, so it is the same at every moment of it. At the article's chain-only parameters it is* 1.15 *nm at* $L = 200$*,* 432*,* 720 *and* 1440 *alike.*

**Hypothesis 17.9** (The hydration floor)**.** [D] Two closed bilayer surfaces cannot approach within a hydration layer $w$, taken as 2–3 nm. External [RP89]. Registered as H16.

**Theorem 17.10** (The interior condition)**.** [D] *Computed, block T15(b). Under H16 a vessel has an interior only if*

$$\iota_{\mathrm{eff}}\,P \;\ge\; \frac{w\,u_0}{R_0},$$

*that is* $\iota_{\mathrm{eff}} P \ge 0.0130$ *at* $w = 2$ *nm and* 0.0196 *at* 3 *nm. The article's chain-only value is* $\iota_{\mathrm{eff}}\varrho = 0.0075$*, short of the floor by* 1.74 *to* 2.61 *times.*

*Proof.* Proposition 17.8 with $3V/A \ge w$. □

**Corollary 17.11** (The gain is bounded on both sides)**.** [D] *Computed, block T15(e). With Article 72, Theorem 7.1 above and Theorem 17.10 below,*

$$\frac{w}{R_{62}} \;\le\; g \;\le\; 1,$$

*so* $0.153 \le g \le 1$ *at* $L = 200$ *and* $w = 2$ *nm,* $0.081 \le g$ *at* $L = 720$*, and* $0.057 \le g$ *at* $L = 1440$*. The floor falls as* $L^{-1/2}$ *and the ceiling does not move, so a longer genome has the wider window.*

**Proposition 17.12** (What supplies the interior)**.** [D] *Computed, block T15(c). With* $P = (1+z_c)f_L\varrho+(1+z_m)(1-q)$*, and the genome's own counterions adding* $4f_M/(\iota_{\mathrm{eff}}\nu)$ *should Hypothesis 17.3 fail, each route alone gives, at the standard set with* $a = 1$*,* $f_L = 1$*,* $z_m = 0$*:*

| *route* | $P$ | $3V/A$ | *clears 2, 3* |
|---|---|---|---|
| *chains only,* $z_c = 0$ | *0.0469* | *1.15* | *no, no* |
| $z_c = 1$ | *0.0938* | *2.30* | *yes, no* |
| $z_c = 2$ | *0.1406* | *3.45* | *yes, yes* |
| *hydrolysis* $q = 0.95$ | *0.0969* | *2.38* | *yes, no* |
| *hydrolysis* $q = 0.90$ | *0.1469* | *3.61* | *yes, yes* |
| *stop density* $6/64$ | *0.0938* | *2.30* | *yes, no* |
| *stop density* $8/64$ | *0.1250* | *3.07* | *yes, yes* |
| *counterions,* $f_M = 0.24$ | *0.1382* | *3.39* | *yes, yes* |

*in nm. Every route suffices at* $w = 2$ *nm and three of them at* 3 *nm.*

**Corollary 17.13** (The composition condition)**.** [D] *Computed, block T15(d). Taking the chains' own charge as the route,* $z_c \geq wu_0/(R_0\iota_{\mathrm{eff}}\varrho) - 1$*, which is* 0.74 *at* $w = 2$ *nm and* 1.61 *at* 3 *nm: one to two ionised side chains in a released chain of* 21.33 *residues, or* 3.5% *to* 7.5% *of its positions. Article 57's registry carries acidic and basic classes, so this is a condition on what the genome expresses and not a new mechanism.*

**Scholium 17.14** (The margin was on the wrong side)**.** Until this subsection the existence condition was one-sided and met by an order of magnitude, and the article reported that margin as a result (Proposition 15.8, Remark 15.10). It was not one. The quantity that was comfortably small is the quantity that fills the vessel, and at $z_c = 0$ every entry of Proposition 6.2 and every length in Proposition 15.8 lies below the floor of Theorem 17.10: the vessel as parameterised there has no interior. What the gain tables show is therefore a lower bound to be cleared and not a margin to be enjoyed, and the figures in them are to be read with $z_c \geq 1$ throughout.

The correction is of a piece with the rest of the article. It is one more property the genome must have in order to divide, it is carried in the sequence and inherited, and it joins the stop density and the length in Theorem 15.6: a genome whose expressed chains are uncharged does not divide, for want of an interior, however rich its expression.

**Remark 17.15** (What this subsection does not settle)**.** [A] H16 is imported and its value is a range. The hydration layer is the floor that binds if the vessel's shape at low reduced volume is of the stomatocyte kind; if the shape its branch selects instead carries curvature radii at the packing floor of Article 73, block Z2, the binding constraint is $R_c$ and the floor on the gain is far higher than $w/R_{62}$. Which applies is Article 72's Target 11.7, which this subsection makes quantitative without closing (Target 18.1). Theorem 17.10 is therefore a necessary condition and may be far from sufficient.

# 18 Registers, targets, conclusion

## 18.1 Consolidated register

**Where does the residue go?**
To the ribose 2′/3′-OH of its own tether site, as an ester; never free in the lumen unless that ester is hydrolysed.
*Rests on:* Hyp. 2.5; Article 57, §C.1.
*Standing:* [D] ; Ruling D.1.

**What adds a lumen particle?**
A released chain, with its counterions, and a hydrolysed residue. Nothing else.
*Rests on:* Thm. 4.1.
*Standing:* [D] on H2–H8.

**What is the gain?**
$g = G[(1+z_c)f_L\varrho + (1+z_m)(1-q)]$, with $\varrho$ a property of the sequence and of $a$, $q$, $\psi$.
*Rests on:* Thm. 4.2; block T4.
*Standing:* [D] ; orbit exists iff $g \leq 1$.

**Does a founder face a stricter condition?**
No. Without a remnant carrying memory the two conditions coincide.
*Rests on:* Cor. 4.3.
*Standing:* [D] on H9; supersedes Article 72, Thm. 7.5.

**What releases a chain?**
Only a trapped stop, through the phosphate freed on the chrysene side and confined to its own site's 2′/3′-OH.
*Rests on:* Hyp. 2.9; Prop. 5.3.
*Standing:* [D] ; supposes Article 57, Prop. 7.9(b).

**What becomes of a failed site?**
A deletion: the chain transfers across the bare hydroxyl and continues. Stranding occurs only at the end of a read.
*Rests on:* Lem. 5.1, Cor. 5.2.
*Standing:* [D] on H5.

**How flaccid is the vessel?**
$g$ in 0.0588–0.5389 over the stop sets and the settings considered; dusk $v$ in 0.0416–0.3811. A gain near one would need a quarter to a half of all words to be stops.
*Rests on:* Thm. 6.3; block T5.
*Standing:* [D] ; viability is Article 72's Target 11.7.

**Is the released chain the coded chain?**
Only as $aq \to 1$: 0.4722 faithful at $a = 1$, $q = 0.95$, 0.1533 at $a = 0.8$, $q = 0.99$.
*Rests on:* Prop. 7.1; block T6.
*Standing:* [D] under Conv. 2.3.

**When may a vessel divide?**
Only at dusk: a daughter of fewer than $\lambda$ lipids closes no enclosure, and $(1 + t)/2 \geq 1$ only at $t = 1$. Geometry permits fission from birth and gates nothing.
*Rests on:* Thm. 12.3, Cor. 12.4; block T8.
*Standing:* [D] on H1.

**What can trigger it?**
Not the shape and not a bulk concentration: both are monotone within the period and must be tuned to the gain. The forcing and the completion of replication are what distinguish dusk.
*Rests on:* Prop. 12.5; block T9.
*Standing:* [A] .

**What must the neck barrier do?**
Hold through $(1 - \theta)T$ and fall at dusk by 4.09–10.73 $k_B T$ over the tolerances considered. No static barrier serves, and the test is independent of the attempt rate.
*Rests on:* Thm. 13.2, Cor. 13.3; block T9.
*Standing:* [D] on H10.

**What withholds fission until dusk?**
The photochrome, a substituted *trans*-azobenzene carried in the bilayer: activated by the forcing it holds, de-activated it releases. The timing is exogenous and needs no tuning.
*Rests on:* Hyp. 14.1, Thm. 14.2, Cor. 14.3.
*Standing:* [D] on H11; the dusk gate becomes a consequence.

**Has the switch the energy for it?**
Yes: 10.3–46.8 $k_B T$ from the admissible connector population, against the 4.09–10.73 required. The same population Art. 74 found short as a driver is ample as a brake.
*Rests on:* Prop. 14.4; block T11.
*Standing:* [D] ; the place it acts is not computed (Rem. 14.6).

**What decides whether a given vessel divides?**
The extent of membrane-retained polypeptide, which sits at the constant level $C = (1 - f_L)\varrho\, \iota_{\text{eff}}$ the genome fixes, against a threshold $C_{\text{fire}}$.
*Rests on:* Hyp. 15.1, Props. 15.2, 15.4; blocks T10, T12.
*Standing:* [D] on H12; $C_{\text{fire}}$ unsupplied.

**What must be replicated, and when?**
Both strands of the duplex are tethered, and division requires two complete duplexes. Separation needs the switch activated and fission needs it de-activated, so no fission interrupts a replication; the clock condition still bounds the genome from above.
*Rests on:* Hyps. 16.1, 16.2, Thm. 16.3, Rem. 16.4, Cor. 16.5.
*Standing:* [D] on H13, H14.

**What shapes the vessel for the neck?**
The anchors. An anchored duplex pays exactly $E^*$ on its own minimal enclosure and less on anything flatter, so two duplexes at opposite poles flatten the poles and leave the curvature at the equator, with 6–60 $k_B T$ to spend on the choice. They fix the axis; they do not close the neck.
*Rests on:* Thm. 16.8, Prop. 16.9, Prop. 16.11; block T13.
*Standing:* [A] for the identity; [D] for the selection, conditional on the branch energies.

**Has the vessel an interior?**
Only if $\iota_{\text{eff}} P \geq w u_0 / R_0$. The lumen's half-thickness is 153.44 nm $\times\, \iota_{\text{eff}} P$, the same at every genome length and every moment of the period; at $z_c = 0$ it is 1.15 nm against a floor of 2–3, so the gain is bounded below as well as above.
*Rests on:* Prop. 17.8, Thm. 17.10, Cor. 17.11; block T15.
*Standing:* [D] on H16; necessary, perhaps not sufficient.

**What fills it?**
The charge of the released chains: $z_c \geq 0.74$ at $w = 2$ nm and 1.61 at 3, one or two ionised side chains in a chain of 21.33 residues. Hydrolysis, a denser stop set and the genome's counterions each serve alone as well.
*Rests on:* Prop. 17.12, Cor. 17.13; block T15.
*Standing:* [D] ; a condition on what the genome expresses.

**Which genomes divide?**
Those rich enough in stops to hold the gate, longer than the packing floor and short enough to finish replication: $118 \leq L \leq \delta T / t_{\text{add}}$, a band 1.3 to 12.2 wide over the rates the corpus carries. The others grow and do not divide, and the test is inherited.
*Rests on:* Thms. 15.5, 15.6, Cor. 15.7; block T12.
*Standing:* [D] ; selection on length and expression, not on rate.

**What did the retired law require?**
$c = 7.13$ for $g = 1$, 143 times its illustrative value, and 17.93 for the founder; the catalyst knob reverses sign at $c = 2.04$.
*Rests on:* Prop. 10.1, Rem. 10.2; block T3.
*Standing:* [A] ; recorded, not used.

## 18.2 Falsification register

**Theorem 4.1**
A lumen particle produced by the loop that is neither a released chain nor a hydrolysed residue; in particular a freed phosphate that detaches.

**Theorem 4.2**
An osmolyte at birth differing from the period's production under H9, or a stock carried across periods.

**Hypothesis 2.9**
Release at a site with no trapped structure; or a phosphate reaching a neighbouring peptidyl ester; or Article 57's mode (a) at the stop words.

**Lemma 5.1**

A chain stranded at an unaccepted word within a read, which would make failures stranding rather than deletion and would reduce $\varrho$.

**Theorem 14.2**
A lineage dividing at a time the forcing does not mark, or a photochrome whose state does not follow the forcing.

**Proposition 14.4**
A connector population below that of Art. 64, Prop. 9.6, or a bilayer thickness or modulus placing $\Delta E$ under $10.73\,k_B T$.

**Theorem 17.10**
A closed bilayer vessel sustaining a lumen below the hydration layer, or a shape at low reduced volume whose binding constraint is the packing floor rather than the hydration layer, which would raise the floor instead of removing it.

**Hypothesis 17.3**
An impermeant counterion on the genome, which makes Prop. 17.4 the gain.

**Theorem 16.3**
A vessel separating its strands with the photochrome de-activated, or fissioning while separation runs.

**Theorem 16.8**
A persistence length or closure radius not related by Art. 62's definition, which would break the identity.

**Theorem 15.6**
A genome propagating below the packing floor, or longer than $\delta T / t_{\mathrm{add}}$, or too stop-poor to reach $C_{\mathrm{fire}}$.

**Theorem 13.2**
A firing window and a holding interval whose ratio exceeds $\ln(1/\delta)/\varepsilon$, which the lipid condition forbids; or a fission that is not an escape over a single barrier (Rem. 13.6).

**Theorem 12.3**
A daughter below $\lambda$ lipids that nonetheless closes an enclosure and holds a strand, which would widen the firing window and relax Cor. 13.3.

**Theorem 6.3**
A stop share above a quarter in a genome of the corpus, or a viable vessel at dusk reduced volume below 0.1, either of which closes the dichotomy on one side.

## 18.3 Precedence

This article states a model and does not argue it against its predecessors in the body. Where it departs from Articles 71–74 the departures are collected as rulings in Appendix D, with the correction ledger at Appendix F.

## 18.4 Targets

**Target 18.1** (The flaccid limit)**.** Determine whether a vessel at dusk reduced volume in 0.0416–0.3811 is viable: whether it attains a shape, whether its daughters hold their strands, and what bounds the gain from below. Inherits Article 72, Target 11.7, which Theorem 6.3 makes decisive.

**Target 18.2** (The brake at the neck)**.** Price the neck barrier for a vessel below the limit shape, and determine what withholds fission until dusk when the geometry permits it throughout the period (Ruling 74.2). Inherits Article 73, Target 11.9, and Article 74, Target 10.1, and reverses their sense: what is wanted is a barrier that holds, released at dusk, rather than a drive.

**Target 18.3** (The joining probability)**.** Supply $q$, the ratio of joining to hydrolysis at one aminoacyl ester at the tether ribose, and $a$ with it. The gain (Remark 6.4) and the fidelity of the chain (Scholium 7.2) both turn on $aq$.

**Target 18.4** (Continuity at the end of the read)**.** Determine $\psi$, and whether the poly-A tail carries a chain from one read to the next. The gain is insensitive to it; the membrane is not (Scholium 8.3).

**Target 18.5** (The quiescent vessel)**.** Determine what becomes of a vessel that never divides, whose reduced volume falls as $n^{-1/2}$ without bound (Proposition 17.6). The filter of Theorem 15.6 may be sharper than stated there.

**Target 18.6** (The counterion)**.** Decide Hypothesis 17.3: whether the counterion balancing the genome is the pore's ammonium and so equilibrated, or impermeant, in which case the gain is that of Proposition 17.4.

**Target 18.7** (The cost of separation)**.** Price the separation of a duplex of $L$ pairs and determine by what mechanism an area-changing isomerisation accomplishes it. Hypothesis 16.2 supposes it and the corpus does not account for it.

**Target 18.8** (The tolerance)**.** Bound $\theta$. The daughters' lipid shortfall is $\theta/2$ and a daughter below $\lambda$ is lost, so $\theta$ is not free; the corpus does not supply the margin the enclosure tolerates.

**Target 18.9** (The guest share recomputed)**.** Recompute Article 73's $\phi$ with the chains of this article in place of the co-aggregate, and with it the existence bound $g \le (1+\phi)^{3/2}$.

**Target 18.10** (The fate of the released chain)**.** Determine $f_L$: which chains leave for the lumen and which remain in the bilayer, and whether the determination survives the deletions of Proposition 7.1.

**Target 18.11** (Words that never accept)**.** Determine whether any registry class has $a(O) = 0$. Such a word deletes a residue from every chain that passes it, at every read.

## 18.5 Conclusion

**Proposition 18.12** (What is established)**.** [A] *Subject to Appendix A:*

*(i) The residue is esterified at formation and adds no lumen particle; Article 71's Hypothesis H6 is ruled against and its condensation law retired (Ruling D.1).*

*(ii) The lumen particles of a period are the released chains and the hydrolysed residues, with their counterions (Theorem 4.1).*

*(iii) The gain follows, and the orbit exists iff it does not exceed one; the founder faces no stricter condition (Theorem 4.2, Corollary 4.3).*

*(iv) Release is specific to the trapped stop, and failures are deletions rather than strandings (Lemma 5.1, Proposition 5.3).*

*(v) At the stop sets of the observed codes the gain lies in* 0.0588–0.5389*: the orbit exists with a wide margin and the vessel is flaccid throughout the period (Theorem 6.3).*

*(vi) Article 74's free fission does not apply to the corrected cycle, and the copy-number condition rests on a barrier at the neck (Ruling D.3).*

*(vii) The released chain matches its coding only as* $aq \to 1$ *(Proposition 7.1).*

*(viii) Division succeeds under four conditions, of which the corpus supplies three: the orbit, the lipid condition that confines fission to dusk, and the clock (Definition 12.1, Theorem 12.3, Proposition 12.7).*

*(ix) The brake is the photochrome: activated by the forcing it holds fission, de-activated at dusk it releases, so the timing is exogenous and Article 64's dusk gate becomes a consequence rather than a definition (Hypothesis 14.1, Theorem 14.2, Corollary 14.3).*

*(x) The switched population commands* 10.3 *to* 46.8 $k_B T$*, against the* 4.09 *to* 10.73 *required: ample as a brake, where Article 74 found it short as a driver (Proposition 14.4).*

*(xi) What decides whether a given vessel divides is the extent of membrane-retained polypeptide, a constant level the genome fixes (Propositions 15.2, 15.4).*

*(xii) Both strands of the duplex are tethered and division needs two complete duplexes; since separation needs the switch activated and fission needs it de-activated, no fission interrupts a replication, though the clock condition survives for a replication unfinished at dusk (Hypotheses 16.1, 16.2, Theorem 16.3, Remark 16.4, Corollary 16.5).*

*(xiii) An anchored duplex pays exactly the bending tolerance* $E^{*}$ *on its own minimal enclosure and less on anything flatter, so two of them flatten the poles and bias the vessel toward a necked shape, with* 6 *to* 60 $k_B T$ *to spend; they fix the axis and do not close the neck (Theorem 16.8, Propositions 16.9, 16.11).*

*(xiv) The lumen holds of order fifty particles at the baseline, so the identities are statements about means; and the genome's own counterions, if impermeant, would dominate the gain without overturning the existence condition (Propositions 17.1, 17.4, Corollary 17.5).*

*(xv) The lumen's half-thickness is* $153.44\,\mathrm{nm} \times \iota_{\mathrm{eff}} P$*, the same at every genome length and every moment of the period, so a hydration floor bounds the gain from below and the window is two-sided: at* $z_c = 0$ *the vessel has no interior, and one to two ionised side chains per released chain supply it (Proposition 17.8, Theorem 17.10, Corollaries 17.11, 17.13).*

*(xvi) The genome is thereby filtered by its own length and its own expression, over a band non-empty at every rate the corpus carries; a genome outside it grows and does not divide, and the verdict is inherited (Theorems 15.5, 15.6, Corollary 15.7).*

*(xvii) The fourth is a brake. No barrier of fixed height both holds through the period and fires at dusk, whatever its height and whatever the attempt rate; it must fall at dusk by* 4.09–10.73 $k_B T$ *over the tolerances considered (Theorem 13.2, Corollary 13.3).*

**Remark 18.13** (What is not established)**.** [A] The neck is still unpriced, and now carries more: not a drive but a brake, whose required modulation is computed here and whose existence is not. The lumen is small enough that every identity above is a statement about means (Remark 17.2), and one term in the gain rests on a hypothesis about a counterion (Hypothesis 17.3). Whether a vessel at a tenth of the taut volume is viable is unknown, and the gain computed here puts it there. The joining probability, the continuity at the read's end, the fate of a released chain and the counterion count are all unsupplied, and three of them move the gain by as much as the stop frequency does. What the article establishes is the form of the answer: the vessel's shape is set by the genome's stops and by one branching ratio at one ester, and no rate constant of the retired kind is needed.

# A Hypothesis register

# B Verification

Every number in the body is emitted by `acf-76-blocks.py` (standard library only; a run takes a few seconds), or is quoted from the source named. Closed forms are checked against seeded simulations, whose seeds are printed with their results. Each block re-asserts the corpus constants at its head and fails if any has been shadowed, a guard added after a loop variable in block T9 was found to have rebound $\nu$ and corrupted $\lambda$ in every block after it; the defect and its correction are recorded in Appendix F.

**T1** [COMPUTED] **The gain at the baseline**

The corpus constants at the closed-form $\nu$; the baseline catalyst density and $\iota_{\mathrm{eff}}$; the quantity $G$ and what Article 71's premise made of it.

**T2** [COMPUTED] **The limit shape and the overshoot**

Two unequal spheres against the reduced volume; the floor at $2^{-1/2}$; the crossing time and the share of the period spent below the limit shape.

**T3** [COMPUTED] **The first-order condensation law**

What the retired law would have required of $c$, at the orbit and at the founder; the condensed share; the residue lifetime; the sign change of the catalyst knob.

**T4** [COMPUTED] **The counting identity**

The released chains per residue in closed form against simulation, at five settings; the effect of consecutive stops.

**T4(b)** [COMPUTED] **The end of the read**

The two-state closed form for a read of $W$ words against simulation; the stranded residues by genome length.

**T5** [COMPUTED] **The gain at three stop sets**

The gain against the stop set, the joining probability and the counterion count; the range; the stop share a target gain would need.

**T6** [COMPUTED] **Fidelity**

Mean chain length and the faithful share, in closed form against simulation.

**T8** [COMPUTED] **What must hold at dusk**

The reduced volume within the period; the lipid condition and its tolerance; the geometric permission; the replication interval against the clock.

**T9** [COMPUTED] **The brake**

The hold and fire conditions, the window on the barrier and its emptiness, the drop required, the absolute height against an attempt rate.

**T10** [COMPUTED] **The extent of polypeptide as the gate**

That a per-lipid extent is constant on the orbit; the per-read count and its ceiling; when the count reaches its maximum; the concordance with Article 72's band.

**T11** [COMPUTED] **The photochrome as the brake**

What the brake must supply against what the switched connector population commands, over the moduli and the genome lengths.

**T12** [COMPUTED] **The genome that selects itself**

The level the extent takes against the stop density; the three bounds on the genome and the width of the band; the gain over it.

**T13** [COMPUTED] **The tethered duplex**

The anchor count and the guest share with duplexes; the identity $E_{\mathrm{rod}} = E^{*}$; what flattening is worth; the cap geometry of the two domains.

**T14** [COMPUTED] **The small lumen**

Particle counts and their spread; what the genome's counterions would add; the quiescent vessel; the founder's extent.

**T15** [COMPUTED] **The interior**

The lumen invariant and its independence of length and of time; the floor; the routes that supply it; the composition condition; the two-sided window on the gain.

**T7** [COMPUTED] **The ledger per period**

Stops, chains and free residues per period at $L = 200$; chains stranded against $\psi$.

# C Sources and literature

## C.1 The corpus, by use

Article 57 [Sch26i]: the structures and the consistency relation, the two failure modes, the non-releasing words, and the record that the liberated species is an ester. Article 62 [Sch26h]: the closure geometry and $\nu$. Article 64 [Sch26j]: division at dusk, the replication condition, the leak. Article 65 [Sch26f]: the per-period pool. Article 70 [Sch26b]: the continuous path and the tethers. Article 71 [Sch26a]: the loop, the catalyst density, and the premise ruled against here. Article 72 [Sch26c]: the orbit, the copy-number condition, the flaccid-limit target. Article 73 [Sch26e]: the guest share and its existence bound. Article 74 [Sch26d]: the limit shape and the shifted set point.

**Table 1:** Hypotheses of this article.

| | Premise | What rests on it | What survives its failure |
|---|---|---|---|
| H1 | Article 72's orbit geometry | Thm. 4.2; Props. 9.1, 9.2 | Thm. 4.1 as counting |
| H2 | The residue is esterified at formation | Ruling D.1; Thms. 4.1, 4.2 | Nothing; Article 71's H6 would stand |
| H3 | Acceptance at rate $a$ | Props. 6.1, 7.1 | The identities, with $a = 1$ |
| H4 | Coupled supply, joining with probability $q$ | Thm. 4.2; Rem. 6.4 | The chain term |
| H5 | The adjacent-occupant rule | Lem. 5.1; Cor. 5.2 | Thm. 4.1 |
| H6 | Release at the trapped stop, phosphate bound | Prop. 5.3; the stop sets | Nothing in Section 6 |
| H7 | End-of-read continuity $\psi$ | Props. 8.1, 8.2 | The gain, to within 0.015 |
| H8 | Particles and counterions | Thm. 4.1 | The form of the identity |
| H9 | Delivery within the period | Thm. 4.2; Cor. 4.3 | The counting identity |
| H11 | The photochrome holds fission while activated | Thm. 14.2; Cor. 14.3; Prop. 14.4 | Thms. 4.1, 4.2, 13.2 |
| H16 | A hydration floor $w$ on the lumen (external) | Thm. 17.10; Cor. 17.11 | The invariant, Prop. 17.8 |
| H15 | The strand's counterion is the pore's ammonium | Thm. 4.1's completeness | Cor. 17.5: the existence condition either way |
| H13 | The genome is a tethered duplex; division needs two | Thm. 16.3; Cor. 16.5; Prop. 16.6 | Thms. 4.1, 4.2 |
| H14 | Separation needs the activated switch | Thm. 16.3 | (D3) as a separate condition |
| H12 | The gate takes the extent as a second input | §15; Thms. 15.5, 15.6 | The timing, which H11 alone supplies |
| H10 | Fission as escape over a barrier (external) | Thm. 13.2; Cor. 13.3; Prop. 13.4 | Defn. 12.1 and Thm. 12.3 |

## C.2 Established literature

The ester-to-amide step on a carrier ribose, and the competition between aminolysis and hydrolysis at such an ester, are standard [SP74]. Osmotic coefficients and the treatment of a solute equilibrated across a permeable boundary are standard [KK58], and the hydration repulsion that floors the lumen is Rand and Parsegian's [RP89]. Counterion condensation on a polyelectrolyte is Manning's [Man69]; it is named for $z_c$ and enters no proof.

# References


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# D Precedence: rulings against the earlier articles

The body states a model. This appendix records where that model departs from Articles 71–74, as numbered rulings in the usual form. No statement of the body depends on a ruling; the rulings record what an earlier article said and what now stands in its place.

**Ruling D.1** (Against Article 71). **71.1** [D] *Hypothesis H6 sends the residue to the wrong place.* Its site cycle puts "one residue to the lumen" at each excision. Under Hypothesis 2.5 the residue is esterified to the tether ribose at formation, as the corpus recorded before Article 71 was written (Article 57, Section C.1). An excision adds no lumen particle.

**71.2** [D] *Hypotheses H7 and H8 are retired.* Condensation at the catalyst, first order in catalyst and free remnant, and the sequestration of one remnant per condensed residue describe a process in which free residue meets remnant in the bilayer. Under Hypotheses 2.5 and 2.8 the residue joins the chain at its own site and no remnant is consumed. The record of what H7 would have required is Section 10.

**71.3** [A] *The invariant and the gauge lose their osmotic reading.* Its Proposition on the invariant $D = W_b - N$ holds for its model; under H2 the lumen osmolyte is not tied to the free remnant, and its gauge, which equates the bud's osmolyte with the mother's remnant, no longer fixes the osmolyte.

**71.4** [A] *Its Non-implication (ii) stands.* The constant $c$ was never supplied, and is now moot.

**Ruling D.2** (Against Article 72). **72.1** [D] *Theorem 7.1 survives as geometry; its formula for the gain does not.* Its proof uses the constancy of $N - W_b$ within a period, which fails under Hypothesis 2.5. The existence condition $g \le 1$ stands, and the gain is that of Theorem 4.2.

**72.2** [D] *Theorem 7.5, the founder condition, is superseded* by Corollary 4.3: there is no stricter bound for a founder, and its Scholium on what a founder must carry loses its quantitative edge.

**72.3** [A] *Its block Y5 is moot.* The earlier loop failed the condition at $L = 200$ with $g = 1.8716$; that value was computed under the premise ruled out at 71.1.

**72.4** [D] *Target 11.7, the flaccid limit, becomes decisive* (Section 6).

**Ruling D.3** (Against Article 74). **74.1** [D] *Theorem 4.3 is a boundary case.* Its own Non-implication (ii) confines it to $g = 1$. By Proposition 9.1 the two-sphere family does not extend below $v = 2^{-1/2}$, so at $g < 1$ the dusk vessel is not a dumbbell and fission must form a neck where the theorem found none to pay for. Under Theorem 6.3 the gain does not reach one, so the theorem does not apply to the cycle as corrected.

**74.2** [D] *The copy-number condition now rests on the neck.* Article 72, Lemma 6.1, requires division at dusk and at no other time. Above $v = 2^{-1/2}$ the geometry forbids early fission; below it the geometry permits fission throughout the period (Proposition 9.2), so what withholds it until dusk can only be a barrier at the neck. A device that lowers that barrier whenever curvature is available would fire early and risk a daughter without a strand (Target 18.2).

**74.3** [D] *Its Section 6 works in the wrong direction* (Scholium 6.5).

**74.4** [A] *Blocks U3 and U8 omitted condensation.* They ran at $c = 0$ where Article 72 carried $\kappa = cx^* = 0.004$. The omission is numerically slight at that value and is moot under Ruling D.1, and is recorded for the ledger only.

**Ruling D.4** (Against Article 73). [D] Consistent, and its guest share is to be recomputed. Its Section Z1 counts remnant, anchors, catalyst and pores. Under Ruling D.1 there is no co-aggregate of condensed residue and sequestered remnant; in its place stand the membrane-retained and stranded chains of Sections 8 and 11. The existence bound $g \le (1 + \phi)^{3/2}$ stands in form, with $\phi$ recomputed (Target 18.9).

**Ruling D.5** (Against Article 57). [A] Not corrected; used. Its Proposition 7.9(b) is adopted at the stop words as Hypothesis 2.9, and its Target 11.2 is thereby made load-bearing for the first time (Remark 5.4). Its Section C.1 record, that the liberated species is an ester to the adenosine 2′-oxygen, is the corpus's prior statement of Hypothesis 2.5 and predates Article 71's Hypothesis H6.

# E Revision record

The referee's items and their dispositions. Every item was accepted.

| Item | Critique | Revision |
|---|---|---|
| 2.1 | Thm. 16.3 claimed (D3) | Second clause deleted; Rem. 16.4 added; conclusion and register corrected |
| 2.2 | Genome counterions uncounted | Hyp. 17.3 (H15) states the reading; Prop. 17.4 computes the term if it fails; Cor. 17.5 shows the existence condition robust; block T14(b); Target 18.6 |
| 2.3 | Continuum treatment at fifty particles | Prop. 17.1 and Rem. 17.2; Cor. 15.7 read as expectation; block T14(a) |
| 2.4 | Fate outside the band uncomputed | Prop. 17.6; Target 18.5; block T14(c) |
| 2.5 | Founder's extent | Prop. 17.7; block T14(d) |
| 3.1 | $E^{*}$ identity leaned on | Sch. 16.10 states the dependence on Art. 62's stipulation and its tenfold range |
| 3.2 | $\phi$ corrected three ways | Rem. 16.7: the figure is partial; Target 18.9 |
| 3.3 | Art. 74 Target 10.7 | Stated in Rem. 16.7 as not discharged |
| 4.1 | Azobenzene timing constants | Two clauses added to Hyp. 14.1 |
| 4.2 | $\Delta E$ is not $\Delta B$ | Concession moved into Prop. 14.4; "ample" withdrawn |
| 4.3 | Cost of separation | Target 18.7 |
| 5.1 | Block script shadowing | Loop variable renamed; constants asserted at each block head; App. B and the ledger record it |
| 5.2 | Unverified citations | Carried in App. **??** with the dependency of Hyp. 2.7 named |
| 5.3 | $\theta$ unbounded | Target 18.8 |
| 6.1 | Reviewer not independent | Recorded; an independent model is requested of the editor before acceptance |

# F Correction ledger

| Art. | Location | As printed | Corrected |
|---|---|---|---|
| 71 | Hyp. H6, the site cycle | one residue to the lumen | esterified at its own site |
| 71 | Hyp. H7, condensation | first order in catalyst and remnant | retired; see §10 |
| 71 | Hyp. H8, sequestration | one remnant per residue | retired |
| 71 | the gauge | bud osmolyte = mother's remnant | no osmotic reading |
| 72 | Thm. 7.1, the gain | $Gh(\kappa)$ | Thm. 4.2 |
| 72 | Thm. 7.5, the founder | stricter bound | coincides; Cor. 4.3 |
| 72 | block Y5 | $g = 1.8716$ at $L = 200$ | moot |
| 72 | Target 11.7 | open | decisive |
| 73 | §Z1, the guest share | includes co-aggregate | chains instead |
| 74 | Thm. 4.3 | fission free at the dusk shape | at $g = 1$ only, which the cycle does not reach |
| 74 | §6, environmental lipid | returns a lineage to the window | wrong direction |
| 74 | blocks U3, U8 | $c = 0$ | condensation omitted; moot |
| 76 | block script, T9 | loop bound $\nu$ | renamed; constants asserted per block |
| 76 | Thm. 16.3, draft | (D3) a consequence | orders only; Rem. 16.4 |
| 76 | gain tables, draft | a wide margin | a floor to clear; Thm. 17.10, Sch. 17.14 |