Universality of Log-Periodic Morphological Variance Under Power-Law Constraint Competition

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Executive Summary

A striking empirical asymmetry appears across both biology and engineering: scaling by multiplicity persists, but scaling by recursive refinement of the same subunit repeatedly halts at narrow, domain-specific bands. The anchor question—why don't we ever see cells made of smaller cells—is the biological instance of the same structural puzzle that appears in semiconductor history as the breakdown of classical MOSFET scaling: chips gained performance mostly by replication (more transistors, more parallelism), but transistor "cells" themselves did not become internally recursive (a transistor made out of smaller transistors) and eventually could not keep shrinking without architectural pivots (FinFET/Tri-Gate, GAA, 3D stacking). The engineering diagnosis of that breakdown prominently involves non-scalable physics (e.g., thermal-voltage limits, leakage optimization, and variability constraints) rather than "insufficient cleverness."

The manuscript formalizes a general claim: Claim (conditional universality). For systems governed (within an operating window) by a finite set of competing constraints that can be modeled as power laws of a characteristic scale , if the constraint

hierarchy recurs under renormalized rescaling—a discrete scale invariance (DSI) condition—then any bounded observable measuring "morphological freedom" must be periodic in periodic oscillatory representation (Fourier series; first mode is sinusoidal).

and therefore admits a log-The core object is a dimensionless morphological variance V (L) ∈ [−1, 1], designed not as metaphysics but as an engineering observable: a bounded proxy for how many qualitatively distinct configurations or morphologies are feasible at a given scale while satisfying active constraints. The model's operational use is to locate innovation bands (constraint competition yields many feasible morphologies) and collapse bands (one constraint dominates; geometry "pins" to a small set of modes). Mathematically, DSI forces periodicity in; physically, recurrence arises when constraint families repeat across scales in similar forms after normalizing by a domain's primitive subunit.

This revision also makes transistor scaling concrete: the semiconductor section is not rhetorical. It uses (i) the empirically observed slowdown of scaling from roughly the 130 nm era onward, (ii) the non-scalability of and subthreshold swing constraints (the "60 mV/decade" thermionic limit), and (iii) explicit, sourced anchors for (silicon lattice parameter from CODATA/NIST) and key architectural pivots (Intel 22 nm Tri-Gate; GAA at ~3 nm-class production).

Two programmatic deliverables accompany the manuscript:

A procedurally generated master plot of across 15 decades of length (illustrative coordinate choice; see figure and code).

A reproducible domain table with computed (L, L , k, θ, V , ∂V /∂ ln L, ∂ V / ∂(ln L)) plus

exported CSV. Download the master plot image Phenomenon and Postulates The motivating observation is not "everything is fractal," nor "all systems share a power law." It is narrower and more falsifiable: 1. Multiplicity scaling is common. Large systems are often aggregates of a stable primitive: tissues of cells, cities of people, chips of transistors. 2. Recursive refinement is selectively forbidden. Cells do not contain a nested hierarchy of smaller cells; transistors are not implemented as nested transistor-cells; beams are not built as recursively thinner beams without changing architecture; and many domains show abrupt regime pivots where continued refinement fails unless the system changes dimensionality (switching topology, adding hierarchy, changing transport mode).

The biological anchor (cells) is sharpened by the empirical extremity of the endosymbiotic power unit: mitochondria retain their own genome while most mitochondrial proteins are nuclear-encoded, making energetic autonomy a carefully gated exception rather than a general rule of "organelles within organelles."

A second biological anchor is scale invariance in differentiated eukaryotic cells: a "typical animal cell" is on the order of 10–20 µm in diameter, a narrow band compared with organism size variation.

The theoretical synthesis is framed (in the spirit of a 1905-style paper) around two explicit postulates plus definitions. Postulate P1 (finite active constraint set). In an operating regime, the system's governing constraints can be reduced to a finite set {C }i m i=1, each scaling as a power law of a characteristic scale

a L ,

a > 0, α ∈i R. The postulate is local-in-regime: it applies to windows where exponent-dominance is empirically observed; it is not asserted globally across all

Postulate P2 (hierarchy recurrence / discrete scale invariance). After renormalizing the description by a domain primitive (an fixed by the system's minimal stable subunit), the family of active constraints recurs

under a discrete rescaling $L \mapsto \lambda L$ through repeated appearance of comparable competing constraints. This recurrence yields DSI for a bounded observable of the system's feasible morphological freedom: $V(\lambda L) = V(L)$ for some fixed $\lambda > 1$. DSI is the load-bearing empirical condition: it is testable and falsifiable, but not derivable from power-laws alone without recurrence.

The remainder of the manuscript makes these postulates operational, derives the forced mathematical form, then stress-tests it across domains and boundary cases. Mathematical Foundation Definition of morphological variance

Let a system at scale feasibility is defined by constraint satisfaction: admit a design/state space $\Omega(L) \subset R$

with measurable volume $\mu(\Omega(L))$, where $\Omega(L) = \{x \in R :n\ g\ (x, L) \le 0, i = 1, \dots, m\}$. Define a raw morphological freedom measure as $M(L) = \log \mu(\Omega(L))$ (or an entropy-like surrogate). The paper uses a bounded, normalized observable

to represent relative freedom across scales: $V(L) = M(L) - \langle M \rangle W \|M - \langle M \rangle \|W\ \infty,W$

$[-1, 1]$ $\langle\cdot\rangle W$ by construction. is an averaging operator over a chosen log-scale window $W \subset \ln L$. This ensures $V(L) \in$ Operationally,

is not required to be computed from first principles in every domain; it is enough that there exists a bounded proxy that consistently tracks whether the feasible region is wide (many distinct morphologies) or narrow (few modes). The domain survey uses constraint-competition pivots (equalities of dominant Ci) as empirical anchors for where

is expected to approach extrema. Lemma on log-linearity of power-law intersections For any two constraints

a Li j

αj a Lj

with α

i □ αj, the intersection scale Lij satisfying C (L) = ij

C (L) ij

j obeys:

a L = ij

a L j

αj ij

⇒ L =ij α −αi j aj (ai

Taking logs gives linear dependence in ln a ln L =ij ln(a /a) j α − αi j

This lemma is deterministic and requires no statistical modeling. DSI implies log-periodicity theorem This is the core mathematical implication used in the paper's second draft. Let

be bounded and satisfy DSI exactly for some $\lambda > 1$

$V(\lambda L) = V(L)\ \forall L > 0$. Define $y = \ln(L/L)0$. Then $V(\lambda L) = V(L) \Leftrightarrow V\ e\ L = (\ln \lambda)\ V(L) \Leftrightarrow \sim (y + V \ln \lambda) = (y), \sim \sim y\ V\ (L\ e)\ (y) =$ admits a Fourier series:. Thus ~ is periodic with period. Any reasonable bounded periodic function ~ $(y) = \infty \sum n{=}1\ A \sin 2\pi n\ n\ (\ln \lambda\ y + \phi\ n)$

Keeping only the first harmonic is a parsimony truncation: $V(L) \approx A \sin 2\pi\ 1\ (\ln \lambda \ln + \phi$

This is the "sine" origin: not aesthetic preference but the lowest Fourier mode of a forced periodic structure under DSI. A comprehensive treatment of DSI and log-periodic corrections is standard in the complex-systems literature; this manuscript uses the minimal theorem needed to justify log-periodicity when DSI holds.

Parameter interpretation and constraints The manuscript uses the working form $V(L) = \sin 2\pi k\ (\ln \lambda \ln + \phi$

with the following procedural commitments: is not a fit knob: it is anchored to the system's primitive subunit. For silicon: the CODATA/NIST • L0 lattice parameter $a = 5.431020511 \times 10$ m−10

• k is constrained to small integers representing an upper bound on how many constraints are simultaneously comparable in the active regime (typically 1–3 in the surveyed cases). This is a structural claim about regimes, not a continuous fit. • ϕ0 a domain, competing pivots become predictive tests. is definitional: it fixes which observed pivot is called "a peak" in . Once that convention is fixed in Candidate bases

and why φ is singled out DSI by itself does not force a unique (golden ratio) as a conjectured universal attractor for two independent reasons:; it forces the existence of some. The manuscript treats λ = φ 1. Fibonacci recursion mechanism. If architecture changes are constrained to reuse the previous two scale states (a minimal memory recursion common in engineered hierarchies), then Ln−1 metaphysics.. This supplies a concrete mechanism for /L → n+1 φ φ without requiring =n+1 L +n 2. Anti-resonance argument (Diophantine robustness). If constraint exponents often simple rationals or small integers, a scaling factor with poorly approximable by rationals are (in practice)

suppresses repeated resonance among exponent intersections. The golden ratio is extremal among irrationals in continued-fraction sense (most badly approximable), making it a natural robustness candidate in a discrete hierarchy selection problem. The paper draws a strict line: log-periodicity requires DSI, but DSI does not require λ = φ. The universality of φ is empirical and is treated as such. Derivatives and classification of extrema Let $y = \ln(L/L)0$. Then: $V(y) = \sin 2\pi k\ (\ln \lambda\ y + \phi$ dV dy $2\pi k \cos 2\pi k\ (\ln \lambda\ y + \phi$

d V2 dy2 $- 2\pi k\ (\ln \lambda \sin 2\pi k\ (\ln \lambda\ y + \phi = - 2\pi k\ (\ln \lambda$

V (y). Thus: - Peaks: Zero crossings: V = +1 dV /dy = 0 d V /dy < V = −1 dV /dy = 0 d V /dy >, representing forced pivots where sign of curvature changes. V = 0 d V /dy =. - Troughs:. - (These derivatives and identities are printed by the reproducible Python script; see the domain table CSV and included code outputs.) Mermaid structure of the theorem chain: flowchart TD A[Finite power-law constraints C_i(L)=a_i L^{α_i}] --> B[Lemma: intersections log-linear in ln L] B --> C[Assumption: constraint-family recurrence under renormalized scaling] C --> D[Discrete Scale Invariance: V(λ L)=V(L)] D --> E[Change of variable: y=ln(L/L0)] E --> F[Periodicity: V(y+ln λ)=V(y)] F --> G[Fourier series on periodic function]

G --> H[First harmonic truncation -> sinusoid] H --> I[Operational program: peaks/troughs/zero-crossings] I --> J[Falsifiability via multi-pivot λ extraction] Empirical Domain Survey This section is deliberately procedural. Each case defines: - the characteristic scale, - an empirically anchored primitive scales, - computed, - the active constraints and derivatives (in a global unshifted scoreboard with a Li, - the equality condition(s) defining pivot ϕ =0 for comparability, plus domain-local anchoring when multi-pivot data exist). The computed table used in this manuscript is exported here:

Capillary length as a clean two-constraint pivot, capillary length.

L = Lc a placeholder primitive).

at molecular scale (order 10−10 10−9 – m; the computation table uses 2.75 × 10−10 m only as Constraints. Compare Laplace pressure to hydrostatic pressure: - −1 C (L) = α =2 +1 (gravity), Δρ g L. -γL−1 (surface tension), α =1 Equality C =1 C2 gives L =c γ Δρg

Using the IAPWS-recommended surface tension formulation for water (e.g., γ ≈ 0.0728 N/m near room temperature) yields L ≈c 2.7 × 10 m−3, consistent with the widely used engineering value.

This is a canonical example where the “variance peak criterion = constraint comparability” is literally the textbook crossover scale. Mountain height limit as strength–gravity competition

L = h, characteristic mountain height. Primitive. solid microstructure scale (order 10−10 10−9 – m). A minimal model compares lithostatic stress C (h) = S α =2 ρgh to material failure stress S C (h) =: -ρgh α =1 +1, - Equality gives

h =* S ρg Using S ~ 200 MPa h ≈* mountains. This is the same “strength vs gravity” mechanism used in the potato-radius literature to explain, the same order as Earth’s largest ρ ~ 2700 kg/m3 7.6 km gives

maximum relief and sphericalization thresholds.

Potato radius as the rocky-body sphericalization pivot

L = R, body radius. Primitive. solid microstructure scale. For a uniform-density sphere, central pressure scales as Setting P =c S

P ~c 2π Gρ R . R =* 3S 2πGρ2

ρ ~ 2700 kg/m3 S ~ 10 Pa8), consistent with the usual rocky-body “potato radius” scale reported across the planetary, the computation gives For rocky density ~ 300 km (literature and summarized in modern treatments. and strength R ≈*

3.1 × 10 m5 Euler buckling as a mode-collapse trough

L = λs, slenderness ratio (dimensionless). (dimensionless). Compare yield stress C (λ) = s σy α =2 σy to Euler critical buckling stress σ ~cr

2 C (λ) = π E/λ: -s s −2 α =1 −2 π Eλ2 s, - Equality gives * λ =s π E/σy

Using representative steel values E ≈ 200 GPa σ ≈y

250 MPa * λ ≈s 88.9, matching the common engineering “transition zone” where stability modes dominate over plastic yield in columns. This is a prototypical variance trough: above * λs, a high-dimensional design freedom (choose section, length, load) collapses into a small set of unstable buckling modes.

Hall–Petch crossover as a strength-maximization peak

L = d, grain size. b, Burgers vector (copper

b ≈ 2.556 × 10 m−10 used in the computation table).

A pure two-law competition can be written (for fixed temperature/strain-rate context): 1) Dislocation-mediated strengthening (Hall–Petch): σ (d) ≈ dis σ +0 k HP −1/2 d

2) Diffusion/GB-mediated softening at very small grains, modeled (at fixed strain rate) as a power law increasing with d simplified form: (i.e., smaller grains require less stress), consistent with diffusion-creep scalings. Using a σ soft (d) ≈ p Ad , p ≈ 2 (illustrative). The maximum-strength grain size occurs near σ (d) ≈ ~ 10 15 nm – range for many metals, with “inverse Hall–Petch” trends appearing below that scale in the nanocrystalline in the observed, giving (d) soft dis σ d* regime.

The computation file implements a copper-specific numeric example with k ≈HP

0.12 MPa m

d =* for the softening branch. anchors a crossover at A 12 nm (chosen as a representative literature scale) to infer the corresponding Turbulence onset as a constraint-competition pivot in Reynolds space (dimensionless controlling group) or equivalently the pipe diameter at fixed fluid

L = Re properties and flow rate. Re for representation. The Reynolds number represents inertial-to-viscous dominance: Re = ρvD μ

A canonical transition in internal pipe flow occurs near Re ~ 2000 2300 – (geometry-dependent, perturbation-dependent), marking a regime pivot from laminar simplicity to turbulence with multiscale vortical structure.

The manuscript treats this as a variance peak in dimensionless scale space: the morphology of admissible flows expands sharply in a narrow band of ln Re, despite the underlying equations being continuous. This case also functions as an early warning for the theory: the “critical” value is not determined by dimensional analysis alone; it includes finite-amplitude stability structure, so the model's job is not to predict Recr from first principles but to use observed pivots to test DSI/log-periodic spacing once multi-pivot sequences exist. Differentiated eukaryotic cell size as a transport-time constraint

= characteristic cell dimension. Primitive. molecular scale (order 10−10 10−9 – m).

A minimal engineering constraint can be written without invoking oxygen specifically: if a cell is internally autonomous, then some key state variables must equilibrate or be sensed/acted upon across distances τ on timescales relevant to regulation. Diffusion gives a timescale: Setting t (L) = τ

t (L) ~ L2

L =*.Dτ With −9 D ~ 3 × 10 m /s τ ~ 0.1 s

for oxygen in aqueous media (a representative small-molecule diffusivity scale) (sub-second coordination target), this gives L ≈* 1.7 × 10 m−5 (≈17 μm), matching the canonical 10–20 μm animal-cell diameter band reported in standard cell biology references. This is not claimed as the only determinant of cell size. It is included as a concrete numeric demonstration of the general claim: internal autonomy forces a narrow scale window because transport time scales as L2, producing steep penalties for scaling either upward (slow coordination) or downward (insufficient physical room for genome + machinery; see below). The "why not cells made of smaller cells" aspect is then a recursive failure claim: if a "cell" were made of smaller "subcells," the transport/coordination and data-integrity constraints would need to be solved at two nested levels using the same mechanism—a condition biology seems to avoid except in the highly controlled mitochondrion/chloroplast pattern (a sequestered, semi-autonomous energy unit heavily governed by nuclear-encoded proteins).

Semiconductor transistor scaling as a concrete multi-pivot stress test This section is intentionally explicit and sourced. Primitive anchor. Silicon lattice parameter a = 5.431020511 × 10 m−10 (CODATA/NIST).

Empirical pivot: slowdown of voltage scaling. In high-performance CMOS, supply voltage tracked a rough proportionality to feature size for a period; then from around the 130 nm era,

scaled slowly if at all. This is not folklore; it is stated directly in published CMOS scaling analyses that emphasize the non-scalability of thermal voltage

and the resulting floor on Vth reduction. Non-scalable physics constraint. The thermionic subthreshold swing floor S =min ln(10) kT /q implies a fundamental linkage between achievable on/off ratio and required gate-voltage separation, which does not improve simply by shrinking geometry. NIST explicitly frames the 60 mV/dec @300 K limit as a "generally considered fundamental limit" for conventional MOSFET swing. Concrete architectural pivots. - The 22 nm Tri-Gate (FinFET-class) move is reported in Intel process-technology publications as addressing fundamental short-channel control limits for continued scaling, providing a clear example of a dimensional pivot rather than continuous refinement of the same planar transistor.

- Gate-all-around (GAA) production at "3 nm-class" is documented in manufacturer communications as a further architectural shift beyond FinFET.

Power wall / regime constraint. The "power wall" is not merely narrative; it is a formally discussed architectural constraint: by ~2005, slowed voltage scaling caused processors to hit the power wall, motivating multicore and other approaches. Power-law envelope + boundary outside the model. The manuscript treats semiconductors as a mixed case: - Some constraints admit power-law representations over windows (e.g., interconnect scaling, capacitance scaling, density scaling). - Key failure modes (subthreshold leakage, tunneling) are exponential in voltage/field, pushing the domain partially outside "pure power-law" applicability. This is not hand-waved; it is the explicit boundary statement. Numerical anchoring used in the computation table. The domain table includes multiple "node-length proxies" (130 nm, 90 nm, 22 nm, ~3 nm) normalized by a and evaluated for λ = φ k = 3 ϕ =0 as a global scoreboard. The point is not to claim "nodes are exact lengths" but to provide a reproducible procedure for testing whether observed pivots cluster into log-spaced bands once a consistent physical length proxy is chosen. Mermaid timeline-style sketch (technological pivots as regime changes): flowchart LR A[~0.5 μm era: Vdd begins scaling with feature size] --> B[~130 nm: Vdd scaling slows] B --> C[~90 nm: leakage/power wall dominates design] C --> D[22 nm: Tri-Gate/FinFET-class pivot] D --> E[~3 nm-class: GAA pivot] E --> F[Next likely pivot: 3D integration / new devices] Neural network scaling as a compute-allocation constraint competition

= training tokens token/parameter (dimensionless baseline). and parameters (or the ratio N D/N). Empirical scaling laws show power-law relationships between loss and scale variables (parameters, dataset size, compute) over wide ranges; the canonical reference gives explicit exponents for parameter-limited and data-limited regimes. A concrete compute-allocation regime pivot was later demonstrated: compute-optimal training requires scaling tokens approximately in proportion to model size ("doubling parameters → doubling tokens"), and a specific compute-optimal flagship model was trained with 70B parameters and 1.4T tokens, outperforming larger undertrained models.

That is a clean "constraint competition" story: past a certain scale, "more parameters with fixed data" enters diminishing returns; competence requires shifting to a different operating band set by the comparable constraints of model capacity and data coverage. Urban scaling as a transport-mode dimensional pivot (worked illustrative example) This case is included because it operationalizes the paper's central heuristic—progress beyond a band requires dimensional transformation—in a setting where the pivot is intuitively geometric. Let population N occupy an approximately disk-like city of radius R(N) = N πρ ρ v is average population density. Suppose a mode of transport with characteristic speed is viable τ only if the city radius does not exceed a distance reachable within a commute time budget

R(N) ≤ vτ . Then the maximum population for that mode is * N (v) = πρ(vτ) .2 walkability threshold is Using illustrative parameters N ≈* that the pivot is quadratic in ρ = 5,000 people/km2 v 9.8 × 104 (vτ) 5 km/h τ = 0.5 h. The exact constants are not claimed universal here; the point is, the computed =walk, so a dimensional pivot in transport (walk → tram → subway) yields discrete jumps in viable scale—precisely the kind of stepping behavior the log-periodic model abstracts. Astrophysical filaments as gravity–pressure competition at Mpc width

= filament thickness scale.

for the Jeans derivation's dimensionless framing (physical primitive could be set by microphysics; the case is evaluated directly in meters/Mpc). A natural candidate thickness scale is the (simplified) Jeans length, obtained by balancing pressure support (sound speed vs) against self-gravity at density ρ

This form appears in standard derivations (e.g., lecture notes showing λ =J πv /(Gρ) s). λ =J πvs Gρ

Using Planck-era cosmological parameters ionized gas sound speed corresponding to H ≈0 T ~ 10 K4 67.4 km/s/Mpc Ω ≈m produces λ ~J 0.315 (to compute) and an ρ

2 Mpc (the computation table's numeric evaluation).

Independent observational/simulation studies report filament radial scales on the order of a few Mpc (thin filament profiles within ≲3 Mpc; characteristic radii ~1–2 Mpc in certain analyses), consistent with that order-of-magnitude prediction. This is a clean example of the manuscript's underlying method: the "morphological complexity band" (filaments and walls) occurs where gravity and pressure are comparable; outside it, geometry simplifies (collapsed halos/stars on one side; void expansion on the other). MEMS stiction as a surface/volume crossover with a fourth-root pivot

= beam length (cantilever). Primitive. solid microstructure scale. Stiction is a canonical MEMS failure mode: at small scales, surface forces compete with restoring elastic forces, and adhesion can dominate. g A minimal energy-balance criterion for a cantilever of thickness , gap W gives a critical length of the form t, modulus E, and work of adhesion L ~* Et g3 2 (W 1/4

(up to order-unity constants depending on contact geometry). The computation table uses a representative silicon modulus and a representative adhesion energy (chosen within the empirically reported range for effective work of adhesion of silicon interfaces). The resulting numeric threshold falls in the tens-of-microns range (≈60 μm for one representative parameter set), matching the engineering intuition that MEMS "get sticky" in exactly the scaling band where surface energy cannot be neglected. Synthesis, Opportunities, and Competing Theories Across domains where the constraints can be cleanly cast as power laws (capillary length; strength–gravity; Euler buckling; simplified Hall–Petch crossover; Jeans scale; MEMS stiction), the same operational story repeats:

A small number of constraints with different exponents compete.

Regime pivots occur where those constraints become comparable.

Those pivots are the only places where a system can "change morphology cheaply" (more feasible shapes/configurations).

Outside those bands, one exponent dominates and geometry collapses into a narrow family. The manuscript's added claim is that if these competitions recur under renormalized scaling (DSI), then the sequence of such pivot bands must be log-periodic, yielding the oscillatory skeleton.

Recursive-architecture opportunities with numeric thresholds This paper treats "recursive architecture" as an engineering action: when you cannot push further within a band, you pivot dimensionally or hierarchically. Semiconductors: move from planar scaling to architectural recursion in 3D.

The historical sequence "Dennard/voltage scaling → power wall → multicore/dark silicon → FinFET/Tri-Gate → GAA" is already a and the subthreshold swing limit sequence of forced pivots. Quantitatively, the non-scalability of define a voltage floor; published CMOS scaling analyses place the practical slowdown of scaling by around 130 nm technology onward. This implies that further large performance gains must come from architecture (parallelism, specialization, 3D integration) rather than "keep shrinking the same planar transistor." Neural networks: pivot from parameter-scaling to data/compute-balanced recursion. Large-language-model results show a concrete regime shift: compute-optimal performance requires increasing training tokens with model size, contradicting earlier undertraining practices, and yields major improvements at fixed compute budgets. The numeric pivot —Chinchilla's 70B parameters trained on 1.4T tokens versus earlier ≈300B-token conventions—is a forward, testable prediction program: for any fixed compute budget, allocate scale across competing constraints instead of pushing only one. MEMS: recursion via surface-energy engineering. The stiction threshold scales as means reducing effective work of adhesion from (5) ≈1/4 predictable extension of functional miniaturization bands. Reported work-of-adhesion ranges for silicon. Therefore, material/coating engineering that lowers adhesion energy yields a quantitatively shifts to 1.5 0.05

0.01 J/m2 L ∝* W −1/4 downward by a factor. That L* interfaces place such reductions within empirical plausibility. Structural comparisons to competing frameworks This manuscript does not claim to replace existing theories; it claims to unify a particular kind of pattern— log-spaced regime pivots—across domains.

Renormalization group (RG). RG explains universality near critical points via continuous scale invariance and fixed points; it expects power-law behavior, not necessarily discrete log-periodic banding unless the system exhibits discrete hierarchy (hierarchical lattices). The present work borrows the rescaling logic but insists on finite constraint families and explicitly targets DSI as the log-periodic trigger. The canonical RG foundation is credited to Kenneth G. Wilson

Self-organized criticality (SOC). SOC explains why many driven dissipative systems sit near criticality with scale-free avalanches; it can generate approximate power laws without tuning. It does not, by default, predict discrete log-spaced architectural pivots for engineered constraints; those pivots correspond more naturally to DSI/hierarchical organization rather than SOC's continuous criticality. Classic SOC framing traces to Per Bak

Entropy-maximization / stochastic emergence. These frameworks can explain broad distributions and typicality, but do not, on their own, force a periodic structure in. The present work's "hard

spine" is DSI → periodicity → Fourier, which is purely structural rather than probabilistic. Dimensional analysis. Dimensional analysis identifies dimensionless groups (Reynolds, Rayleigh,

etc.) and tells you what combinations matter; it does not determine where pivot values occur, nor does it produce log-periodic sequences without additional discrete structure.

Counterexamples, Stress Tests, and Theory Boundaries A universality claim becomes stronger when it states exactly what it does not cover. Scale-free networks Claims that “real networks are scale-free” are empirically contested; large corpora tests show that scale-free degree distributions are far from universal. This matters here: if a system is truly scale-free with no characteristic pivot scales (within the observed range), then “finite constraint hierarchy with recurrence” is not the right model. The theory predicts: either (i) hidden finite-size cutoffs introduce bands, or (ii) the domain falls outside the model’s applicability. (The canonical network claim is cited to the Broido–Clauset line of work; Aaron Clauset is the relevant named anchor.) Continuous fractals Continuous self-similar fractals exhibit continuous scale invariance, not discrete. In such objects, DSI does not apply; therefore strict log-periodicity is not forced. However, discrete fractals (constructed in finite iterative steps) do exhibit DSI by construction and therefore can carry log-periodic signatures in observables —precisely consistent with the theorem chain. Critical phase transitions Criticality (in the RG sense) is again continuous scale invariance; log-periodic corrections appear when the system’s renormalization has discrete hierarchical structure rather than a continuous fixed point. Therefore, critical systems are not counterexamples; they are boundary tests that discriminate whether the underlying rescaling is continuous or discrete.

Chaotic systems and period-doubling universality

Period-doubling routes to chaos exhibit universal geometric ratios in parameter-space scaling (Feigenbaum constants), showing that discrete rescaling ratios can be structural invariants in dynamical systems. That makes chaos a stress test in favor of the possibility of universal ratios, but it also warns against over-claiming one specific number: different universality classes have different constants. The named anchor here is Mitchell Feigenbaum . Falsifiability Program The paper’s load-bearing empirical claim is not “the world is sinusoidal.” It is: 1) Some domains exhibit DSI in a morphologically relevant observable. must appear. 2) If DSI holds, log-periodicity in 3) A candidate may cluster across domains; λ = φ is a conjecture to be tested, not assumed.

Minimal falsification datasets A domain

falsifies the log-periodic thesis (for that domain) if:

F1 (primitive anchoring failure). No physically meaningful primitive subunit exists to define without “moving it” post hoc (e.g., if matching pivots requires shifting primitive). The semiconductor case is intentionally anchored with far from any plausible aSi from CODATA/NIST.

F2 (no DSI in the observable). After defining a domain-specific morphological observable (L) (e.g., count of feasible architectures, number of stable modes, performance frontier curvature), the emp

log-spectrum of Vemp contains no statistically significant periodicity in. For this, a minimum of 3–5 distinct pivot bands over ≥2 decades is necessary to separate “one-off crossover” from a banded structure.

F3 (multi-pivot spacing inconsistent with any single). Given pivot scales

{L }n, estimate per-ln Ln vs.. If residuals are inconsistent with any constant-λ^ domain from linear regression on spacing model in (after accounting for measurement/proxy uncertainty), DSI is rejected.

F4 (universal λ^ claim rejected). If multiple domains each show internal DSI but their inferred values split into incompatible clusters not explainable by known universality-class differences, the “single across reality” conjecture fails even if the weaker per-domain DSI thesis survives.

Concrete extraction procedure for Given ordered pivots L <1 L <2 ⋯ < Ln, define DSI predicts Δ ≈i

(constant). Estimate Δ =i

ln L −i+1 ln L .i

n − 1 n−1

∑ i=1 Δ , λ^ exp(), and test constancy via variance of Δi under known uncertainty. This is the decisive test the manuscript proposes but does not pretend already completed for every domain; it is the key forward program needed to turn the scaffold into a stringent empirical theory. Reproducibility artifact The accompanying CSV includes computed (L, L , k) (λ = φ, ϕ =0 reproducible starting point for multi-pivot extraction once richer datasets are substituted for proxy points.. It is intentionally not presented as proof; it is a the global scoreboard convention, and first/second derivatives under θ(L) V (L) plus

To reproduce the definitions and derivatives used throughout: - DSI → log periodicity is sourced to the DSI/ log-periodicity literature. The named anchor here is Didier Sornette

- Semiconductor scaling constraints are sourced to CMOS scaling analyses and device physics limits; key named anchors include Robert H. Dennard and Mark Horowitz

- The 22 nm Tri-Gate pivot is anchored to Intel’s published process technology description.

- GAA production at 3 nm-class is anchored to Samsung Electronics’s release.

- Neural scaling and compute-optimal pivots are anchored to the power-law scaling literature and the compute-optimal training result; named anchors include Jared Kaplan and Jordan Hoffmann - Cell-size numeric anchors are grounded in standard cell biology references and measured diffusion coefficients. - Cosmological parameters and Jeans-length derivation are anchored to Planck-era parameter reporting and standard Jeans analysis.

- MEMS stiction and adhesion-energy ranges are anchored to MEMS stiction literature and silicon interface adhesion measurements.

https://www.seas.upenn.edu/~leebcc/teachdir/ece299_fall10/Horowitz05_Scal
https://www.seas.upenn.edu/~leebcc/teachdir/ece299_fall10/Horowitz05_Scal

[PDF] A 22nm SoC Platform Technology Featuring 3-D Tri-Gate and High ... https://people.eecs.berkeley.edu/~pister/147fa14/Resources/Intel22nm.pdf?utm_source=chatgpt.com

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