The Body Listens to Its Own Echo

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Abstract

A rhythm in the body is not a number. It is the time a wave needs to come back to itself in step. We reached this conclusion by failing three times. We started from the Vacuum.Net theory. First we tested whether human rhythms sit on a fixed ladder of scales. Then we tested whether rhythms within one person couple in ratios built only from the factors 2 and 3. Each test was written down before the data were seen. Absolute positions on the ladder were no closer to the rungs than chance (31 rhythms, p = 0.21). Coupling ratios reported in 15 studies contained the factors 5 and 7 again and again. We also analysed raw heart and breathing recordings of 40 healthy people. There, ratios built from 2 and 3 never beat rivals of the same size.

The failures point to a different reading of the same theory. In Vacuum.Net a strand that meets itself closes into a ring. A seam closes only when the returning wave matches its start. That is self-resonance. Its measure is not a universal number. It is the ratio between a rhythm and the round trip of its own loop. The heart offers a clear case. It works most lightly when its beat matches the return of its pressure echo from the arteries. That ratio is reported to be the same in every mammal, from mouse to elephant. With age the echo comes back too early. We read ageing as a growing comma: the widening gap between a rhythm and its own return. We end with predictions that can be tested in each person. We also state the limits of what has been shown.

1. Introduction: from numbers to self-resonance

We usually describe health in fixed numbers. A resting heart rate of 60. Fifteen breaths a minute. A sleep cycle of about 90 minutes. Behind these numbers lies a quiet assumption. Nature keeps a table, and a healthy body sits at the right entries.

A theory of scales invites the same assumption in a stronger form. The Vacuum.Net theory proposes that the universe is built as a ladder of closures. Then perhaps every rhythm of the body sits on a rung of that ladder. And perhaps the rhythms inside one body relate in the theory's simple steps: doubling and tripling.

We took that idea seriously enough to try to break it. Section 3 reports three tests, each fixed in writing before any data were opened. All three failed. Sections 4 to 7 explain why that failure is useful. It shows that we read the theory as a list of numbers. Its own core rule speaks of something else: a wave that returns to itself. Read that way, the theory predicts not where a rhythm sits, but how it fits its own loop. The heart and its echo in the arteries show what that means in practice. Ageing then appears as the slow loss of that fit.

The article is self-contained. Section 2 gives the parts of the theory that are needed. The appendix gives the methods, data and code, so every number can be checked.

2. The Vacuum.Net theory in brief

Vacuum.Net starts from one rule and builds everything from it. Only five elements are needed here.

1. **One strand.** There is one strand. Every distinction is a passage along it. The first passage fixes a direction, so each step carries one of three values: forward (+1), still (0) or back (−1). These are trits.
2. **Closure selects.** Of all the patterns the strand can make, only the ones that close survive. In a window of three steps, 9 of the 27 possible patterns close.
3. **Ring.** When a strand meets itself it can stand, meet or ring. A ring carries one unit forward, as in balanced-ternary counting: 1 + 1 + 1 = 10. Doubling marks a meeting, tripling marks a ring.
4. **The seam rule.** A seam closes only if what returns equals what left: B = A. In wave terms, the returning wave must arrive in phase with its own start.
5. **The comma.** Closure is never perfect. Successive closures occur at depths 1, 2, 5, 12, 41, 53 and 306. At each one a small remainder is left over. At depth 53 that remainder is 0.2086%. The remainder is not an error. It is what keeps the system moving.

To place a measured quantity on the ladder, the theory uses units derived from hydrogen. The length unit is $S_o = 4.5588 \times 10^{-8}$ m. The time unit is $T_o = 1.5207 \times 10^{-16}$ s. The depth of a quantity is $n = \log_3(\text{quantity} / \text{unit})$. On this scale the human body (about 1.96 m) lies near depth 16. A heartbeat lies near depth 33 (0.845 s). A human life lies near depth 53 (93.4 years).

The seam rule (element 4) is the one that matters most below. A strand that meets itself and closes is a wave that resonates with itself. Light that circles back in step with its own start is the simplest picture of it.

3. Three tests of the fixed-number hypothesis

All three tests failed to show that the body prefers the ladder or the factors 2 and 3. Each protocol was written down before the data were opened. It fixed the test, the threshold (one-sided, $\alpha = 0.05$) and the exclusion rules.

Test	Question	Data	Result
1. Absolute positions	Do human rhythms lie closer to whole rungs than chance?	31 spontaneous rhythms of healthy people, from published means	Mean distance 0.229 rung against 0.25 by chance; p = 0.21. Not supported.
2. Ratios in the literature	Are coupling ratios n:m within one person built only from 2 and 3?	68 reported ratios from 15 studies (brain, heart–breath, step–breath)	Ratios with 5 and 7 found in 6–7 of 15 studies. Excess of 2-and-3 ratios vanishes once small ratios are allowed their known advantage.
3. Raw recordings	At equal frequency ratio and equal size, do 2-and-3 couplings beat others?	Heart and breathing of 40 healthy people, 2 h each, 15,904 windows	No case where a 2-and-3 ratio beats a smaller or equal rival.

Test 1: absolute positions

For each rhythm we computed its depth on the ladder and its distance to the nearest whole rung. If rhythms ignore the ladder, that distance is spread evenly between 0 and 0.5, with a mean of 0.25. The observed mean was 0.229 ($p = 0.21$). Rhythms with a small spread between people did no better (14 rhythms, mean 0.272, $p = 0.72$). When we replaced the base 3 by every base from 2 to 5, base 3 ranked 86th of 301.

One cluster stood out after the fact: four ultradian rhythms lie near depth 41 (92.4 minutes). They are the migrating motor complex of the gut (86 min), the rectal motor complex (92 min), the LH pulse in women (94 min) and the sleep cycle (96 min). Because this was noticed after looking, it is a lead, not evidence.

Test 2: ratios in the literature

The theory seemed to predict that rhythms inside one person lock in ratios like 1:2, 1:3, 2:3, 3:4 or 4:1. Ratios with a factor 5 or 7 should never occur. We collected every n:m ratio reported in 15 studies of healthy people. The strict form failed at once: 5:1, 5:2 and 7:2 appear again and again. In Ironman athletes, for example, 7:2 heart–breath locking was seen in 6 of 14 athletes after the race (Angelova et al. 2021).

The statistical form looked better at first. Suppose all candidate ratios are equally likely. Then 31.3 of the 68 ratios should be built from 2 and 3. We found 43 ($p = 0.002$). But every oscillator system locks more easily in simple ratios. And 2:1, 3:1 and 4:1 are both simple and built from 2 and 3. Giving small ratios even a mild advantage removed the excess:

Null model	Expected	Observed	p
All candidates equal	31.3	43	0.002
Weight $1/(n+m)$	40.4	43	0.29
Weight $1/m^2$ (locking-zone width)	44.4	43	0.69
Weight $1/(n \cdot m)$	47.6	43	0.92

Test 3: raw recordings

The literature cannot separate the two explanations. So we went to raw data: the Fantasia database on PhysioNet. It holds 20 young and 20 old healthy people, each resting for two hours. In each 30-second window we measured how strongly heart and breath locked at every candidate ratio. From this we subtracted the chance level: the same measure with the breathing shifted by 10 to 50 minutes. Candidates were compared only at the same ratio of heart rate to breathing rate and the same m.

The pre-registered test passed: 29 of 40 people favoured ratios built from 2 and 3 ($p = 0.0002$). The check then showed why. The decisive pairs are those where the 2-and-3 ratio is the *larger* one:

Comparison (same m, same detuning)	Does 2-and-3 win?	p
6:1 against 5:1	No difference (16 of 31)	0.32
6:1 against 7:1	No (7 of 20)	0.97
9:2 against 7:2	No (12 of 37)	0.995

Comparison (same m, same detuning)	Does 2-and-3 win?	p
8:3 against 7:3	No (5 of 13)	0.83

Wherever 2-and-3 won (3:1 and 4:1 over 5:1, 8:3 over 10:3), it was also the smaller ratio. Our protocol should have matched on n as well as m. The formal verdict is "passed". The honest verdict is that size decides, not the factors 2 and 3.

4. What the failures teach: no table, only self-fit

The three tests asked the wrong question of the right theory. They treated the ladder as a table of allowed numbers. But the theory's own rule for what survives is the seam rule. A wave closes when it comes back to its own start in step. That rule names no number. It names a relation between a wave and its own path.

If every rhythm closes on its own loop, three things follow, and each matches what we found.

- **Absolute periods differ between people.** Every body has its own lengths, stiffnesses and speeds. So its loops have their own round-trip times. A test of absolute positions mixes those loops and finds no rungs (test 1).
- **Rhythms with different loops need not stand in 2:3 steps.** The heart and the lungs close on different paths. Their ratio follows from those paths, not from a shared table (tests 2 and 3).
- **Simple ratios still win.** Two loops that must meet are most easily held together in simple ratios. That is ordinary physics of coupled oscillators, and it is what we saw.

So the measurable quantity is not the period of a rhythm, nor its ratio to another rhythm. It is the ratio between a rhythm and the round trip of its own loop. That is where self-resonance can be seen. It is also where the theory can claim something that ordinary tables cannot.

5. The heart and its own echo

The heart already shows self-resonance, and it has been measured. Each beat sends a pressure wave into the aorta. The wave travels down the arterial tree. It reflects at branches and narrowings and comes back toward the heart. Whether that echo helps or hinders the heart depends on when it arrives.

Pahlevan and Gharib captured this timing in one dimensionless number, the wave condition number:

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\mathrm{WCN} = \frac{\mathrm{HR} \cdot L_{\mathrm{eff}}}{\mathrm{PWV}}
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Here HR is the heart rate, L_eff the effective length of the arterial path and PWV the speed of the pulse wave. They report that the heart's pulsatile workload is lowest at WCN ≈ 0.1. This optimum holds for all mammals, regardless of size (Pahlevan & Gharib 2011; Pahlevan & Mazandarani 2020). A worked example for a young adult: 1.2 beats per second × 0.5 m / 6 m/s = 0.10.

Read through the theory, this is the seam rule in the body. A mouse and an elephant have very different heart rates. Yet each heart beats in the same proportion to its own echo. The heart does not aim at a number. It tunes to its own return. The beat and its loop form one closed ring. The ring is healthiest when what comes back fits what was sent.

6. Ageing as a growing comma

With age the heart drifts out of step with its own echo. Two independent lines of work show this.

- **The wave condition number falls with age.** Pahlevan and Mazandarani report a WCN near the optimum of 0.1 in young adults. It declines with advancing age in both women and men (2020).
- **The echo returns too early.** Elastic fibres in the aorta are replaced by stiffer collagen. Stiffening "increases aortic PWV and shortens the return time of the reflected BP wave". This raises the load on the left ventricle in systole and reduces coronary flow in diastole (Hashimoto 2017).

In the language of the theory, the seam no longer closes cleanly. What returns no longer matches what was sent, and the gap grows each decade. That gap is the comma of section 2: the small remainder that every closure leaves. In a young body the remainder is small and keeps the system moving. In an ageing body it widens until the ring works against itself.

This reading makes ageing a matter of fit, not of worn parts. Each part may still work. What fails is the timing between a rhythm and its own return.

The coupling between heart and breathing shows a similar, partial picture. Iatsenko and colleagues studied 189 healthy people aged 16 to 90. The respiratory influence on the heart weakens with age and becomes "less stable and more time-variable". Yet the total time spent synchronized does not change with age (Iatsenko et al. 2013). Our own data agree on the second point. Young people were locked in 48% of windows and old people in 45%. The difference is not significant ($p = 0.21$).

7. Consequences and testable predictions

The self-fit reading makes claims that a table of numbers cannot. Each can be tested in single persons.

1. **Every lasting rhythm has a loop it tunes to.** For the heart that loop is the arterial tree. For breathing it is the elastic and resistive mechanics of lungs and chest. Otis and colleagues proposed in 1950 that resting breathing frequency minimises the work of breathing. Schramm revisits the question with a model of the respiratory system's own mechanics. He criticises parts of the original calculation (Schramm 2022). The prediction: in each person, breathing rate follows that person's own respiratory time constant. It follows it more closely than any population norm.
2. **The ratio to the own loop is conserved; the period is not.** Across people and species the period should vary widely. The ratio to the own loop should stay close to one value, as the WCN does for the heart.
3. **Ageing is measurable as drift from self-fit.** The distance of a person's WCN from 0.1 should predict cardiac strain better than age alone. The same should hold for any rhythm whose loop can be measured.
4. **A decisive test of table against self-fit.** The cluster near 92.4 minutes (test 1) can now be put to a fair question. If the ladder sets the number, individual sleep cycles should cluster near 92.4 minutes regardless of the person. If self-fit sets it, cycle length should vary between people and follow some property of each person. That test should be written down before the data are seen.

For readers the practical message is simple. There is no correct heart rate for everyone. There is a correct fit between your beat and your own vessels. What keeps the vessels supple, such as regular movement, keeps the echo in time.

8. Limits of this work

- **The WCN optimum comes from one research group.** The claim that WCN ≈ 0.1 holds for all mammals has so far been reported by Pahlevan and colleagues. The age-related early return of the echo is confirmed independently (Hashimoto 2017). The universal 0.1 is not yet.
- **The self-fit reading was formed after the tests failed.** It explains the failures, but explaining is not predicting. It earns its place only if the predictions in section 7 hold on new data.
- **Test 2 rests on incomplete data.** Four key papers could not be opened (Schäfer et al. 1998, Bartsch et al. 2012, Bramble & Carrier 1983, Bernasconi & Kohl 1993). Most studies report ratios only in figures. So ratios were often counted once each.
- **Test 3 had a design flaw.** The protocol matched candidates on m but not on n. That allowed the primary test to pass on size alone. The decisive comparisons were added after the primary result.
- **The depth-41 cluster is post hoc.** It was noticed after looking and has not been tested.
- **Harmonics can mimic ratios.** In brain rhythms, a beta peak at exactly twice alpha can be a harmonic of a non-sinusoidal alpha wave. It is then not a separate rhythm (Schaworonkow 2023). This affects the brain part of test 2.

Annotated references

The theory

- **Konstapel, J. Vacuum.Net Theory: Foundations 9.2 and Physics 9.0.** Constable Research, Leiden, 2026. The source of the strand, closure, ring, seam rule, closure depths and comma used in section 2. Published at constable.blog.

The heart and its echo

- **Pahlevan, N. M. & Gharib, M. (2011). Optimum heart rate to minimize pulsatile external cardiac power.** APS Division of Fluid Dynamics meeting. Abstract. A hydraulic model with artificial aortas shows an optimum heart rate that minimises the heart's pulsatile power. A reflection site can create "constructive wave conditions". The experimental basis of section 5.
- **Pahlevan, N. M. (2013). A systems approach to cardiovascular health and disease with a focus on aortic wave dynamics.** PhD thesis, Caltech. Thesis. The full development of the aortic wave-dynamics work.
- **Pahlevan, N. M. & Mazandarani, S. P. (2020). Estimation of wave condition number from pressure waveform alone and its changes with advancing age in healthy women and men.** Frontiers in Physiology 11:313. Article. Defines WCN = HR × L_eff / PWV. States the optimum of 0.1 as universal among mammals, citing Pahlevan & Gharib 2014 (J Biomech). Reports its decline

with age. Central to sections 5 and 6. Note: the universality claim is cited, not tested, in this paper.

- **Hashimoto, J. (2017). Central hemodynamics for management of arteriosclerotic diseases.** Journal of Atherosclerosis and Thrombosis 24(8):765–778. Article. Independent review. Aortic stiffening with age raises pulse wave velocity and shortens the return time of the reflected wave. This loads the heart. The second source for section 6.

Breathing

- **Schramm, W. (2022). The (human) respiratory rate at rest.** Journal of Mathematical Biology 85:60. Article. Revisits Otis, Fenn & Rahn (1950), who proposed that resting breathing minimises respiratory work. Criticises their turbulent-flow assumption. Basis for prediction 1 in section 7.

Heart–breath coupling (tests 2 and 3, section 6)

- **Schäfer, C., Rosenblum, M. G., Abel, H.-H. & Kurths, J. (1999). Synchronization in the human cardiorespiratory system.** Physical Review E 60:857–870. Record. Young swimmers at rest show 3:1, 5:2, 7:2, 8:3, 4:1 and 11:4 locking, with transitions between them.

- **Bartsch, R., Kantelhardt, J. W., Penzel, T. & Havlin, S. (2007). Experimental evidence for phase synchronization transitions in the human cardiorespiratory system.** Physical Review Letters 98:054102. Preprint. 112 sleepers; 3:1 dominates in REM, 4:1 in light and deep sleep; 5:1 and 6:1 also common.

- **Iatsenko, D. et al. (2013). Evolution of cardiorespiratory interactions with age.** Philosophical Transactions of the Royal Society A 371:20110622. PDF. 189 healthy people aged 16–90. Respiratory influence on the heart weakens and becomes more variable with age. Total synchronization time does not change. Most common ratio 4:1.

- **Ahn, S., Solfest, J. & Rubchinsky, L. L. (2014). Fine temporal structure of cardiorespiratory synchronization.** American Journal of Physiology – Heart and Circulatory Physiology. Preprint. Uses the Fantasia database also used in test 3. We checked its counts of 1:2, 1:3 and 1:4 locking per group against the text.

- **Angelova, M. et al. (2021). Effect of stress on cardiorespiratory synchronization of Ironman athletes.** Frontiers in Physiology 12:612245. Article. Full per-athlete table of ratios and durations. We recounted it. 7:2 locking common after the race.

- **Bettermann, H., Cysarz, D. & Van Leeuwen, P. (2002).** BMC Physiology 2:18. Article. **Cysarz, D. et al. (2004).** BioMedical Engineering OnLine 3:44. Article. Night-time coordination at 3:1, 4:1, 5:1, 7:2 and 9:2.

- **Mrowka, R., Patzak, A. & Rosenblum, M. (2000).** International Journal of Bifurcation and Chaos 10:2479–2488. PDF. Newborns: 5:2 more common in the first weeks, 4:1, 7:2 and 9:2 later.

- **Bahraminasab, A. et al. (2008).** IET Systems Biology 2:48–54. PDF. Switching between close ratios such as 2:11 and 1:5.

Step–breath coupling (test 2)

- **McDermott, W. J., Van Emmerik, R. E. A. & Hamill, J. (2003).** European Journal of Applied Physiology 89:435–444. PDF. Eight ratios checked. 2:1 dominant in 71.1% of trials, then 3:2 and 1:1. 5:2 was the only other. Checked by us against the text.
- **Daley, M. A., Bramble, D. M. & Carrier, D. R. (2013).** PLoS ONE 8:e70752. Article. Runners: 2:1 most common, also 3:1, 2.5:1 and 3.5:1.
- **Hoffmann, C. P., Torregrosa, G. & Bardy, B. G. (2012).** PLoS ONE 7:e45206. Article. Cycling: modes at 1/4, 1/3 and 1/2 breaths per pedal cycle.
- **O'Halloran, J. et al. (2011).** ISBS conference proceedings. Paper. Walking: 2:1, 3:1, 4:1 and 5:1.

Brain rhythms (test 2)

- **Palva, J. M., Palva, S. & Kaila, K. (2005).** Journal of Neuroscience 25:3962–3972. Resting cross-frequency synchrony mainly at 1:2 and 1:3.
- **Siebenhühner, F. et al. (2020).** PLoS Biology 18:e3000685. Article. After correction, genuine cross-frequency coupling mainly at 1:2 and 1:3.
- **Haegens, S. et al. (2014).** NeuroImage 92:46–55. Beta/alpha peak ratio 1.995 in 32 people.
- **Schaworonkow, N. (2023).** Shows that many beta peaks at twice alpha are harmonics of a non-sinusoidal alpha wave. The main caveat for the brain data.

Data

- **Iyengar, N. et al. (1996). Age-related alterations in the fractal scaling of cardiac interbeat interval dynamics.** American Journal of Physiology 271:R1078–R1084. The study behind the Fantasia database on PhysioNet, used for test 3.
- **Goldberger, A. L. et al. (2000). PhysioBank, PhysioToolkit and PhysioNet.** Circulation 101:e215–e220. The standard citation for PhysioNet.

Appendix: methods, data and code

Test 1. 31 spontaneous rhythms of healthy people were taken from published means (seven sources checked directly, among them Duffy 2011, Wolpert 2020, Rieger 2018, Bull 2019, Quer 2020, Cox 2017 and Kumar 1989). Each period was converted to a depth $n = \log_3(\text{period} / T_o)$. The test statistic was the mean distance to the nearest whole number. The null distribution was uniform on [0, 0.5], evaluated by 10^6 simulations. Base sensitivity was checked by replacing 3 by every base from 2 to 5 in 301 steps.

Test 2. For each study, all reduced ratios n:m within the study's tested range and up to its largest m formed the candidate set. The chance that a reported ratio is built only from 2 and 3 was the share of such ratios among the candidates. The total was tested with an exact Poisson-binomial test. Sensitivity analyses weighted candidates by $1/(n+m)$, $1/m^2$, $1/(n \cdot m)$ and $1/(n \cdot m)^2$.

Test 3. Fantasia database, all 40 records (250 Hz ECG and respiration, about 120 minutes each). R-peaks from the supplied beat annotations. Heart phase rose linearly by 2π between beats. Breathing phase came from the Hilbert transform of the respiration signal band-passed at 0.05–0.7 Hz. Windows of 30 s with 15 s steps. Windows with less than 90% valid signal were dropped. For each candidate n:m (m = 1,

2, 3; |n/m − ρ| < 0.5) the locking index was γ = |mean exp(i(mϕ_heart − nϕ_breath))|. The chance level was the same index with breathing shifted circularly by 10, 20, 30, 40 and 50 minutes. Primary test: per person, we took the difference in excess locking between 2-and-3 ratios and other ratios. Only cells of equal m and detuning were compared. The difference was tested over persons with a one-sided Wilcoxon signed-rank test.

Availability. The Fantasia data are public on PhysioNet. The protocols, data tables and analysis scripts (Python) are available from Constable Research on request.