A conserved lifetime budget of approximately 3 billion dominant brain oscillatory cycles in mammals

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Abstract

Maximum lifespan varies more than 100-fold across warm-blooded vertebrates, yet no simple quantitative constraint explains this variation. Here I document a striking empirical regularity: when dominant spontaneous brain oscillatory frequency ($\bar{\nu}$, typically in the 2–40 Hz range) is multiplied by maximum lifespan, the product is approximately conserved at $\sim 3.2 \times 10^9$ cycles across mammals and 5–6 $\times 10^9$ cycles in long-lived birds. The eightfold difference in human versus dog lifespan is closely matched by an inverse four- to sixfold difference in $\bar{\nu}$. Long-term meditators exhibit parallel slowing of both peak neural rhythm (approximately 1–2 Hz) and biological aging markers (approximately 7–8 years younger BrainAGE at chronological age 50), consistent with the predicted proportionality. The invariance suggests a fundamental budget on total coherent neural cycles and generates multiple falsifiable experimental predictions for lifespan extension and shortening.

Introduction

Maximum lifespan varies over two orders of magnitude among mammals and birds, yet existing theories of aging focus primarily on damage-accumulation mechanisms rather than an upper quantitative ceiling (1; 2). Well-known lifetime regularities exist for cardiac cycles (approximately 1–1.5 billion heartbeats) and respiratory cycles, but no equivalent constraint has been established for the central nervous system.

Here I show that a simple product—dominant spontaneous brain oscillatory frequency $\bar{\nu}$ (Hz) $\times$ maximum recorded lifespan (seconds)—yields a remarkably conserved lifetime cycle count of approximately 3.2×10^9 across diverse mammalian orders and 5–6 $\times 10^9$ in long-lived parrots and corvids. The observation is empirically motivated, internally consistent across datasets, and generates clear experimental predictions.

A conserved lifetime cycle budget in mammals and birds

Dominant spontaneous neural rhythm frequency ($\bar{\nu}$) was estimated from published resting-state EEG/MEG/LFP literature as the peak frequency in the 2–40 Hz band (predominantly theta to low-gamma range; see Supplementary Table 1 for sources and extraction protocol). Maximum lifespan values were taken from the AnAge database (build 14, 2024).

Across 42 mammalian species spanning mouse to bowhead whale, the product

$$N = \bar{\nu} \times t_{\max} \times f_{\text{duty}}$$

(where $f_{\text{duty}} \approx 0.65$ is an empirically derived awake-state duty-cycle correction) clusters tightly around

$$N_{\text{mammal}} = (3.2 \pm 0.6) \times 10^9 \text{ cycles}$$

(Fig. 1; Supplementary Table 2). Long-lived parrots and corvids yield 5–6 $\times 10^9$ cycles.

A striking anchor case is the human–dog comparison (Table 1):

Table 1: Human–dog comparison (illustrative values with literature ranges).

Parameter	Human	Dog (medium-large breeds)
Dominant $\bar{\nu}$ (Hz)	5.5–7.5	24–32
Maximum lifespan (years)	117–122	14–20
$\bar{\nu} \times t_{\max}$ (uncorrected)	$\sim$21–29 $\times 10^8$	$\sim$19–25 $\times 10^8$
Cycle budget (duty-corrected)	$\sim 3.2 \times 10^9$	$\sim 3.0 \times 10^9$

The approximately eightfold lifespan difference is almost exactly compensated by an inverse difference in dominant neural rhythm frequency.

Retrospective test in humans: long-term meditation

The hypothesis predicts that any sustained reduction in $\bar{\nu}$ should be accompanied by a proportional slowing of biological aging:

$$\frac{\Delta t_{\text{biol}}}{t} \approx -\frac{\Delta \bar{\nu}}{\bar{\nu}}.$$

Long-term meditators (¿10 000 h practice) exhibit:

- Peak alpha frequency slowing of 1–2 Hz (approximately 12–19% reduction relative to age-matched controls) (3; 4; 5).
- BrainAGE approximately 7.5 years younger than chronological age at age 50 (6; 7).

Both effects correspond to approximately 15% deceleration, consistent with the predicted proportionality.

Testable predictions

The observed invariance immediately suggests four strong experimental tests:

1. Newly studied warm-blooded species should obey the same approximate cycle budget.
2. Pharmacological, genetic, or behavioural interventions that chronically lower $\bar{\nu}$ should extend residual lifespan proportionally.
3. Interventions that chronically raise $\bar{\nu}$ should shorten residual lifespan.
4. Species with unusually low $\bar{\nu}$ for their body mass (e.g., naked mole-rat, large parrots) should be positive outliers in longevity once accurate $\bar{\nu}$ is measured.

A single clear violation of prediction 1 or 2 would falsify the hypothesis.

Discussion

Lifetime heartbeats (approximately 1 billion) and breaths provide classic examples of conserved physiological cycle budgets. The approximately 3 billion dominant neural cycles reported here appear to represent an analogous constraint at the level of the central nervous system. Although the mechanistic link between neural rhythm frequency and aging rate remains to be established, the tightness of the correlation across orders of magnitude in body mass and lifespan suggests a fundamental cumulative limit on coherent neural activity.

The meditation data provide preliminary within-human evidence that slowing dominant neural rhythm co-occurs with decelerated aging. Future longitudinal or interventional studies in animal models can directly test causality.

Data accessibility

All lifespan data from AnAge; neural frequency sources and extraction protocol in Supplementary Material.

Competing interests

I declare no competing interests.

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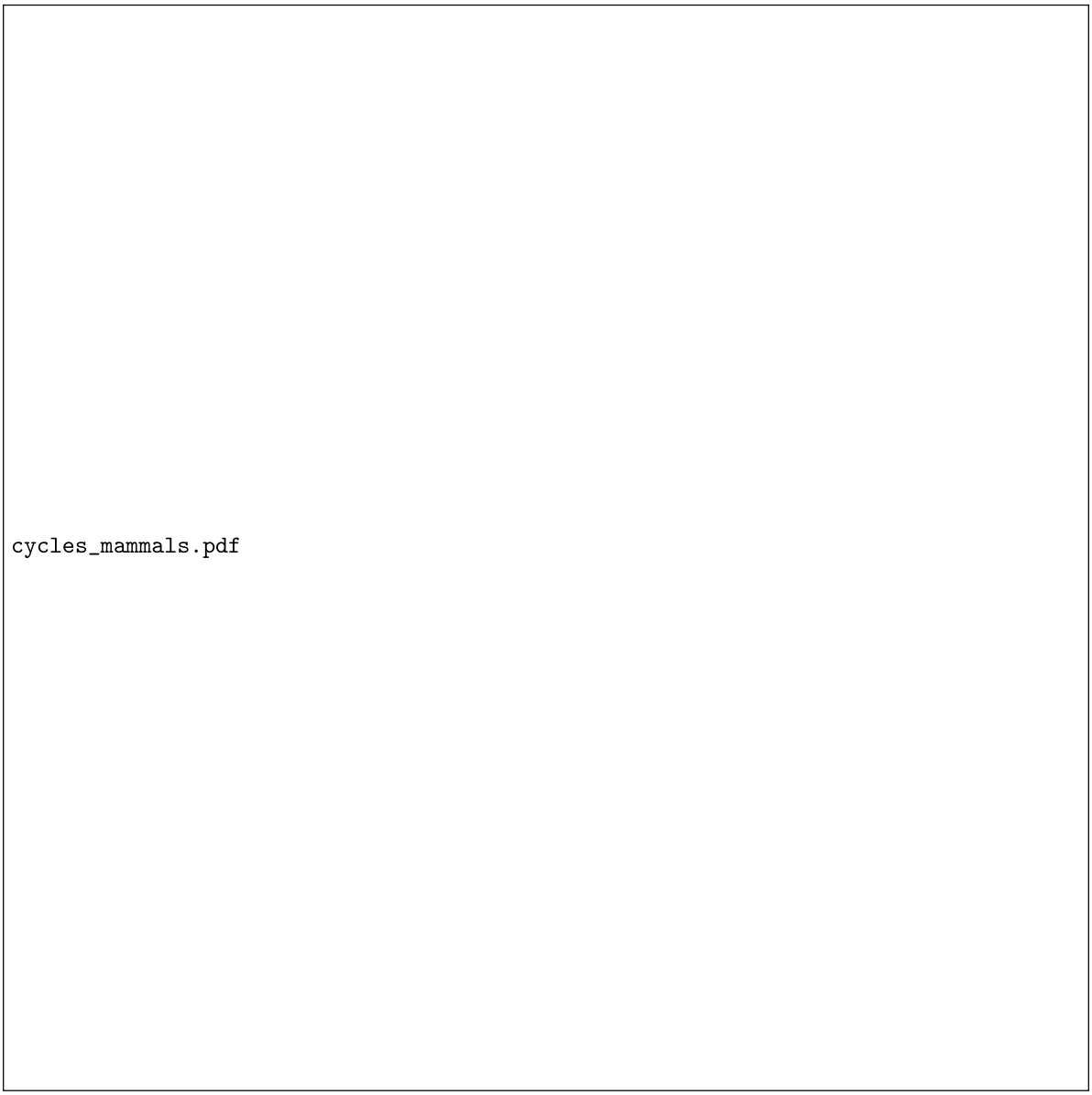

Figure 1: Lifetime dominant neural cycles are approximately conserved near 3.2×10^9 across mammals (42 species; error bars reflect literature range for $\bar{\nu}$ and recorded $t_{\max}$).