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Peer Review

Review of: "Aging as Cybernetic Attractor Decay: Beyond the Stochastic-Programmed Dichotomy"

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This manuscript presents an ambitious and intellectually engaging attempt to reinterpret biological aging through a cybernetic and information-processing framework. By moving beyond the classical dichotomy of programmed versus stochastic aging, the author proposes that aging may be more appropriately understood as a progressive loss of informational fidelity across hierarchical regulatory networks.

The manuscript is clearly written, conceptually rich, and succeeds in stimulating cross-disciplinary thinking between biology, cybernetics, and complex systems theory.

One of the major strengths of the paper lies in its integrative ambition. Rather than replacing existing frameworks, the proposed model has the potential to function as a higher-level interpretative structure capable of accommodating both stochastic damage and regulatory constraints within a unified perspective. In this regard, the manuscript contributes to an increasingly important shift in aging research from molecule-centred explanations toward systems-level organisation.

That said, several aspects would benefit from further clarification in order to enhance the rigour and operational value of the framework.

First, key concepts such as computational fidelity, regulatory entropy, and attractor dynamics require more explicit biological grounding. While these constructs are theoretically compelling, the manuscript would be strengthened by clearer indications of how they could be empirically measured or approximated in biological systems. Without such operationalisation, there is a risk that parts of the argument may be interpreted as metaphorical rather than mechanistic.

Several measurable proxies may help anchor this construct empirically. For example:

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- age-associated increases in cell-to-cell transcriptional variability (e.g., single-cell RNA-seq dispersion metrics) could serve as indicators of declining regulatory precision.

- variance-based measures of DNA methylation patterns across cells or tissues may reflect loss of regulatory stability rather than mere damage accumulation.

- the capacity of biological networks to recover from perturbations (stress responses, immune challenges, metabolic shifts) could serve as a functional readout of preserved computational integrity.

Second, the cybernetic model would benefit from a more formal articulation. The inclusion of schematic models, quantitative examples, or illustrative network representations could substantially improve conceptual precision and accessibility, particularly for readers less familiar with computational frameworks.

Third, although the manuscript attempts to transcend the program–stochasticity dichotomy, the relative contribution of regulatory architecture versus stochastic perturbation remains somewhat underspecified. Clarifying whether the proposed framework primarily reframes these processes or assigns them different causal weights would improve theoretical transparency.

Additionally, stronger integration with evolutionary reasoning could further reinforce the argument. Since regulatory architectures themselves are products of selection, a more explicit discussion of how evolutionary pressures shape informational stability versus plasticity would help anchor the cybernetic perspective within established biological theory.

Importantly, the value of this manuscript should not be judged primarily by immediate translational applicability. Its principal contribution lies in its heuristic potential — that is, its capacity to reorganise how aging processes are conceptualised and to generate new lines of empirical inquiry.

Overall, this is a thoughtful and provocative theoretical contribution that addresses a fundamental question in aging biology. With additional conceptual sharpening and greater emphasis on operational definitions, the manuscript has the potential to stimulate productive discussion across multiple disciplines.

Declarations

Potential competing interests: No potential competing interests to declare.