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The New Frontier of Human Longevity

From Aging as Destiny to Bodily Preservation as a Scientific Duty

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Medicine – Artificial Intelligence – Technology Axis
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> *"Aging is a physicochemical process that we can medically intervene in. Death is not a necessary part of life, but a maintenance failure that we can and must postpone indefinitely."*
>
> **— Aubrey de Grey, Biomedical Gerontologist and Director of the SENS Research Foundation**

Abstract:

The Technology-Health axis constitutes the most significant transformative paradigm of the 21st century, radically redefining the understanding of human aging. This monograph critically analyzes this convergence, starting from Aubrey de Grey's thesis that conceptualizes aging as a medically correctable "maintenance failure".

This document sequentially examines the transition from digital medicine to datafied medicine; the role of Artificial Intelligence as a cognitive partner in diagnosis and therapeutics; and the emergence of Geroscience as a discipline for extending healthy life expectancy.

The research projects future scenarios including hyperpersonalized medicine through digital twins, the technological offensive against cancer and neurodegenerative diseases, and the theoretical horizon of Longevity Escape Velocity.

As a fundamental contribution, it establishes the imperative necessity of a Future Laboratory as a specialized think tank, with three core functions: systemic prospective analysis, management of updated information at near-real-time speed, and selective knowledge dissemination. The conclusion underscores that proactive longevity management, supported by this prospective intelligence capability, constitutes the most relevant scientific and civilizational challenge of our time, transitioning from a "repair model" toward "predictive maintenance" of human health.

Analytical Table of Contents:

1. Management Summary:

This monograph critically examines the transformative interface between technological development and medical science, a domain conceptualized as the "Technology and Health axis".

Starting from Aubrey de Grey's provocative thesis—which classifies aging as a correctable "maintenance failure"—the analysis focuses on how this convergence redefines the paradigm of human longevity. Through a sequential expository methodology, it explores the transition from digital to datafied medicine; the role of Artificial Intelligence as an amplifier of diagnostic and therapeutic capabilities; and the emergence of Geroscience as a discipline for extending healthy life expectancy. The research projects future scenarios of hyperpersonalized medicine through digital twins and neurotechnology, and analyzes the disruptive approach toward age-related pathologies.

As a fundamental contribution, this document integrates a Prospective Action Framework that argues the imperative necessity of developing a Future Laboratory as a specialized think tank.

This laboratory stands as the decisive instance to close the gap between exponential technoscientific progress and its strategic assimilation, through three core functions:

1. The development of systemic analyses that decipher technological trajectories;

2. The management of updated information at near-real-time speed, filtering and curating the massive flow of emerging data; and

3. The selective dissemination of that knowledge to the various actors of the ecosystem.

The conclusion underscores that proactive longevity management, supported by this prospective intelligence capability, stands as the most significant scientific and civilizational challenge of the XXI century.

2. General Introduction: From Biological Destiny to Technological Obligation

Aubrey de Grey's quote that heads this document is not just a bold statement; it is the axis around which a historical paradigm shift revolves.

We find ourselves in the transition from an era where aging was understood as an inevitable biological destiny, toward another where it is conceptualized as a set of physicochemical processes accessible to intervention, maintenance and repair. The Technology and Health axis is the terrain where this new paradigm materializes, redefining the foundations of biology, medicine and the human experience of health and disease.

This monograph is born with the objective of methodically examining that transformation and arguing that the convergence of exponential technologies and life sciences is transforming gerontology from a descriptive discipline into an avant-garde interventionist field. However, the speed of this transformation generates a critical gap between technoscientific progress and its effective translation into policies, strategies and clinical applications.

Therefore, this document not only maps the present and future of the axis, but also establishes the operational necessity of a Future Laboratory as critical infrastructure of prospective thinking, designed to analyze, curate and disseminate knowledge in such a way that society navigates complexity and transforms disruptive uncertainty into strategic opportunity, materializing the vision of medicine that addresses the "maintenance failure" systematically and scientifically.

3. Methodological Development:

3.1. The Data Revolution: From Intuitive to Quantified Medicine:

Medical practice undergoes a fundamental epistemological change: the transition from an art based on clinical intuition toward a science supported by objective and quantifiable data. This change surpasses the mere digitalization of medical records—an already overcome phase—and penetrates the era of integral health datafication. Medical Big Data, composed of complete genomic sequencing, high-resolution images, electronic records of millions of patients and constant information flows from wearables, constitutes the new substrate of clinical research and practice.

The true transformation resides in the capacity to process and interpret this ocean of information. Thanks to Artificial Intelligence and machine learning, hidden patterns and subtle correlations can be identified that predict the risk of developing diseases like diabetes or Alzheimer years before the appearance of the first symptom. This marks the transition from reactive to predictive and preventive medicine.

The Internet of Medical Things materializes this principle, creating through connected pacemakers, glucose sensors and other devices an ecosystem of continuous and passive monitoring, establishing a "hospital at home" that allows early interventions and optimizes chronic disease management. Telemedicine, for its part, consolidates itself as the vital bridge of a hybrid care model, democratizing access and facilitating continuous and personalized follow-ups.

Together, these advances form the foundation of medicine that is simultaneously Predictive, Preventive, Personalized and Participatory.

3.2. Artificial Intelligence as Cognitive Partner in Clinical Practice:

Artificial Intelligence (AI) does not present itself as a replacement for the medical professional, but as a cognitive partner that amplifies their capabilities. By processing data volumes that exceed human analytical capacity, AI algorithms offer quantitative and probabilistic perspectives that enrich clinical experience. In image diagnostics, deep learning algorithms have demonstrated effectiveness that competes with experienced radiologists in detecting specific pathologies, functioning as an automated verification system that mitigates fatigue and cognitive biases.

Its impact extends to pharmaceutical research, where AI predicts molecular interactions, repositions drugs and identifies biomarkers, significantly reducing time and costs of preclinical research. In daily practice, clinical decision support systems integrate the patient's electronic health record with the most updated scientific evidence to generate highly personalized diagnostic and therapeutic recommendations, warning of adverse drug interactions and optimizing complex treatment schemes, especially in oncology.

This implementation brings with it important ethical and technical considerations. AI performance depends critically on quality, quantity and diversity of training data, whose bias can perpetuate inequalities in healthcare. The "black box problem" of some deep learning models questions the interpretability of their decisions, a fundamental aspect for accountability and clinical trust. Therefore, responsible adoption requires a robust regulatory framework that guarantees algorithmic transparency, equitable access and privacy protection, always maintaining ultimate responsibility with the medical professional.

3.3. Longevity and Healthy Life Expectancy: Redesigning the Aging Paradigm:

The increase in life expectancy achieved in the last century poses an even more ambitious challenge: the targeted extension of "healthy life expectancy". Geroscience postulates that aging is the main risk factor for the most prevalent pathologies (cancer, neurodegenerative, cardiovascular and metabolic diseases) and that intervening in its fundamental molecular mechanisms—cellular senescence, telomeric shortening, mitochondrial dysfunction—could delay the simultaneous appearance of all of them.

Predictive and preventive precision medicine is crucial for this. Advanced genomic sequencing, integrated with epigenomic data and multimodal biomarkers, allows creating remarkably precise "biological clocks" that measure an individual's actual physiological age. This enables designing personalized interventions—nutritional, pharmacological and lifestyle-oriented—aimed at slowing biological aging. Among the most innovative therapeutic approaches are senolytics, drugs that selectively eliminate senescent cells or "zombie cells", which in preclinical models have demonstrated capacity to rejuvenate tissues and prolong healthy lifespan. AI accelerates the discovery of new senolytic molecules and the identification of optimal candidates for clinical trials.

In parallel, regenerative medicine and gene therapies through stem cell technologies and gene editing systems like CRISPR-Cas9 offer the perspective of repairing or regenerating tissues and organs damaged by aging. The immediate and achievable goal is not the search for immortality, but "morbidity compression": living more years in robust health, minimizing the phase of frailty and dependence.

3.4. Future Horizons I: Toward Hyperpersonalized Medicine and Human-Machine Symbiosis:

The near future of clinical practice will transcend genomics-based personalization to evolve toward dynamic and adaptive hyperpersonalization.

The cornerstone of this paradigm will be the Digital Patient Model or "digital twin": a high-precision computational representation that integrates omic data, microbiome data and real-time flows of physiological information. This twin would function as a virtual testing platform, allowing:

• Advanced therapeutic simulation for in-silico evaluation of efficacy and side effects of pharmacological regimes before their administration.

• Precise disease prediction through long-term simulations that identify individual health trajectories.

• Scientific lifestyle optimization by modeling the impacts of specific diets and habits on future health.

Brain-Computer Interfaces (BCI) and neurotechnology represent another crucial dimension. Beyond restoring motor functions, next-generation BCIs will be integrated into general medicine for:

• Predictive monitoring of pathological states through capture of neuroelectrical markers for neurodegenerative diseases years before their clinical manifestation.

• Closed-loop brain modulation therapies that detect depressive or anxious states and automatically administer focused brain stimulation.

• Cognitive prostheses for patients with brain damage, replacing compromised memory or executive functions.

3D bioprinting of tissues and the development of organ-on-a-chip systems will complete this ecosystem, providing personalized substrates for in vitro therapeutic testing. In this horizon, medicine will begin to offer not only healing, but also optimization of physical and cognitive capabilities, raising fundamental questions about equity and the very definition of human nature.

3.5. Future Horizons II: The Technological Offensive Against Cancer and Neurodegenerative Diseases:

The convergence of Artificial Intelligence and biotechnology redefines the approach to the two great age-associated pathologies: cancer and neurodegenerative diseases. In oncology, progress is being made toward "deep precision oncology".

Multimodal imaging algorithms integrate radiological images, digital histopathology and liquid biopsy sequencing to characterize tumors with unprecedented biological resolution, predict metastases and track their clonal evolution. AI simultaneously revolutionizes immunotherapy design, analyzing the neo-antigen profile of each tumor to design personalized cancer vaccines and specific CAR-T therapies.

For neurodegenerative diseases, the paradigm shift is equally profound. Preclinical diagnosis through digital biomarkers allows analyzing subtle patterns in speech, gait or motor skills—captured by everyday devices—to identify hints of Parkinson's or Alzheimer's up to a decade before their clinical manifestation. Therapeutically, AI applied to protein design—as demonstrated by AlphaFold—accelerates the development of "pharmacological chaperones", molecules designed to guide proteins like Tau or alpha-synuclein toward their correct folding, preventing their toxic aggregation. Neural circuit modulation through latest-generation brain implants that "resynchronize" affected circuits with millimeter precision represents another revolutionary front.

Long-term, it is plausible that cancer transforms into a chronically manageable or curable disease and that neurodegenerative diseases shift from being irreversible to conditions that can be prevented, stopped or reversed in their initial phases.

3.6. The Final Horizon: Longevity Escape Velocity and its Civilizational Implications:

The theoretically most challenging concept is "Longevity Escape Velocity" (LEV), which postulates a future where science could extend life expectancy by more than one year for each year lived. The scientific strategy for approaching this horizon, proposed by the SENS Research Foundation, is based on systematically addressing the seven types of molecular and cellular damage that constitute the essence of aging.

This does not imply completely preventing damage, but developing periodic rejuvenation therapies that recurrently repair this wear. Among them: second-generation senolytics, telomerase gene therapy strategies, systems to eliminate mitochondrial mutations, immunotherapies for senescent cell elimination and nanomedicine platforms for protein aggregate removal.

The materialization of this project requires critical key technologies like advanced medical nanotechnology for molecular-level cleaning functions and an eventual General Artificial Intelligence to handle data complexity and real-time design of personalized therapies.

The implications of LEV radically transcend the biomedical realm. Urgent questions of generational and distributive equity arise, with the risk of creating a biological caste of economically privileged "immortals". Planetary sustainability would face unprecedented challenges in a world without natural generational renewal, requiring new economic paradigms. The psychology of extreme longevity confronts us with the nature of existential motivation, affective relationships and the search for meaning in potentially secular life. Philosophers like Heidegger argued that finitude gives life meaning; therefore, optional death could undermine creative impulses and cultural renewal. The search for LEV thus becomes our species' definitive technological and philosophical project.

4. Prospective Action Framework: The Future Laboratory as Critical Node of Health Intelligence

The complexity, speed and disruptive potential outlined in preceding sections make creating a Future Laboratory not an option, but a first-order strategic necessity. This laboratory must operate as a think tank for prospective and anticipatory thinking, functioning as the central nervous system designed to address the triple problematic of the Technology-Health axis: information overload, knowledge fragmentation and difficulty of anticipation. Its mission is threefold: To analyze the future with prospective rigor, curate information with agility and communicate knowledge with strategic precision.

4.1. Imperative 1: The Need for Prospective and Systemic Analysis

The first core function of the Future Laboratory is to transcend descriptive analysis and embrace systematic, evidence-based prospective. This involves permanent technology observation, tracking weak innovation signals in laboratories and deep tech startups, identifying emerging technologies before their commercial maturity. Using methodologies like scenario analysis and system dynamics, the laboratory must model the trajectories of critical technologies (like CRISPR or senolytics) and project their cascading impacts on the health system and society. In parallel, it must conduct anticipatory assessment of the ethical dilemmas and legal gaps these technologies raise, thus preparing the ground for responsible governance. Without this deep analysis, investment decisions, health policies and professional training will be made on reactive and obsolete foundations.

4.2. Imperative 2: The Management of Updated Information at Near-Real-Time Speed

In an ecosystem of exponential change, information has an extremely short expiration date. Therefore, the Future Laboratory must operate as a knowledge curation and synthesis platform at near-real-time speed. This function materializes in high-value filtering and curation, using AI to extract from the vast ocean of information the most relevant and rigorous knowledge. It must generate periodic synthesis reports that consolidate fragmented knowledge, offering comprehensive, updated overviews of the developmental state of specific fields. Finally, it must maintain a dynamic and interactive knowledge base that serves as a continuously updated reference for researchers, clinicians and legislators. This capability transforms raw data into actionable intelligence.

4.3. Imperative 3: The Selective and Strategic Knowledge Dissemination

The most valuable information is useless if it doesn't reach the right recipient, in the adequate format and at the opportune moment. Dissemination cannot be uniform; it must be strategic, selective and adapted. The Future Laboratory must act as translator or interpreter of the future for different audiences: for legislators and regulators, through creation of policy briefs that distill technical complexity into clear public policy options; for the clinical community, generating anticipatory practice guidelines and summaries of applicable new technologies; for industry and investors, producing market trend reports and technological competition analyses; and for citizenry and media, designing rigorous educational content that fosters scientific literacy and informed social debate. This triangulation ensures that prospective knowledge is effectively disseminated to all links of the healthcare value chain.

5. Synthetic Conclusion: Beyond Maintenance, Toward Strategic Life Management

The monographic analysis presented conclusively demonstrates that the synergistic convergence of technology and medicine reconfigures the Technology and Health axis as the most transformative innovation domain of our time.

Aubrey de Grey's provocative vision ceases to be mere speculation and becomes a tangible scientific research program. The transition toward a predictive, preventive, personalized and participatory medical model is irreversible. The projected future horizons—from hyperpersonalized medicine to the theoretical possibility of Longevity Escape Velocity—draw a panorama where proactive aging management will become the central axis of medical practice and health policies.

However, this unprecedented technological progress is accompanied by an equally monumental ethical and social responsibility. The challenges of equity, sustainability and existential significance demand collective deliberation and anticipation capability that traditional structures cannot provide. Here is where the Future Laboratory reveals itself as critical infrastructure. By fulfilling its triple mission of analysis, curation and strategic communication, this laboratory stands as the beacon that illuminates the fog of disruptive uncertainty and allows us to transit from a "failure repair" model toward "predictive maintenance" of human health.

In the race between education and obsolescence, where the future of global health is at stake, the Future Laboratory is the indispensable tool to guarantee that society not only adapts to change, but leads it with wisdom, ethics and a clear vision of the desirable future. Science provides the means to transcend biological limits; it now corresponds to a formally organized collective intelligence to determine the ultimate ends of this unprecedented power and forge a longevity future that is not only technologically advanced, but also ethically sound and humanly meaningful. We transition from being passive spectators of our biological decline toward active managers of our vital potential.

The "maintenance failure" could, effectively, come to its end.

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