EVOLUTIONARY THEORIES OF AGING AND THE DEVELOPMENT OF LONGEVITY SCIENCE

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Abstract: The process of aging is deeply embedded in the biology of all living organisms and has been a subject of scientific research and philosophical reflection for centuries. This article explores the historical evolution of aging theories, focusing on evolutionary perspectives, and examines various concepts of longevity extension. Key evolutionary theories discussed include programmed death (Weismann), mutation accumulation (Medawar), antagonistic pleiotropy (Williams), and the disposable soma theory (Kirkwood and Holliday). Longevity concepts range from immortalism and radical longevity to transhumanism, posthumanism, singularity, and bioconservatism. The article includes comparative tables and illustrative graphics to enhance understanding. The goal is to provide a comprehensive framework for the potential business development of longevity technologies, integrating historical context, scientific achievements, and economic prospects.

Keywords: aging; healthspan; lifespan; evolutionary theories; longevity

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1. INTRODUCTION

Aging is a complex, dynamic, and time-dependent process characterized by the gradual accumulation of cellular damage and a progressive decline in an organism's ability to regulate homeostasis. This decay in structure and function increases vulnerability to disease and mortality over a lifetime. Ageing is generally regarded as the cumulative impact of a series of deleterious biological processes which gradually render an organism increasingly vulnerable to mortality with age (Mooney et al. 2016; López-Otín et al. 2023). From a life-history perspective, senescence is defined as the physiological deterioration of an organism that results in declining survival and/or reproduction with age (Stearns 1998). Longevity is a general term encompassing various measures of life length, including maximum observed life span, maximum potential life span, and mean life span (life expectancy) (Goldwasser 2001).

Over millennia, considerable thought has been invested into understanding why organisms age. However, it was only with the introduction of natural selection that a meaningful theoretical framework could be used to solve this problem (McAuley 2024). The resulting evolutionary theories form the intellectual core of gerontology, explaining the ultimate causes of aging. Separately, the profound global increase in life expectancy over the last century has necessitated the development of socioeconomic theories to understand its impact on growth and society (Mitsi 2023).

Evolutionary gerontology provides the ultimate, "why," explanation for aging, asserting that aging is not deliberately programmed but rather results from a lack of selection pressure to maintain the soma indefinitely after reproductive viability has waned. The translation of this evolutionary understanding into mechanistic, "how," research constitutes modern longevity science, a field catapulted into the spotlight by the growing social and economic concerns of an aging global population.

This paper will first outline the dominant classic evolutionary theories of aging. It will then establish the intellectual link between these theories and the mechanistic hallmarks of aging that drive modern longevity research.

1.1 Methodology

The methodology for examining evolutionary theories of aging and the development of longevity science draws upon a diverse corpus of scientific literature spanning multiple decades and disciplines. This analysis incorporates peer-reviewed journal articles from fields including evolutionary biology, gerontology, genetics, and population biology, tracing the conceptual development from early twentieth-century theories to contemporary molecular approaches.

Primary sources include seminal theoretical papers proposing and refining concepts such as mutation accumulation, antagonistic pleiotropy, and disposable soma theory, alongside empirical studies testing these frameworks across model organisms. The investigation also considers review articles and monographs that synthesize evolutionary perspectives on senescence, revealing how theoretical paradigms have shifted in response to new experimental evidence and technological capabilities.

Beyond formal academic publications, this methodology encompasses the broader discourse surrounding longevity science as it has evolved from purely theoretical evolutionary biology into an applied, translational field. Popular science books, conference proceedings, research commentaries, and institutional reports document how evolutionary theories of aging have influenced practical longevity research programs and vice versa. This multifaceted textual analysis allows for examination of not only the scientific content of evolutionary aging theories but also their reception, interpretation, and application within the emerging longevity science community. By analyzing this rich documentary landscape, the methodology captures both the intellectual genealogy of key concepts and the social processes through which evolutionary theories have been validated, contested, and integrated into modern approaches to extending healthspan and lifespan.

2. LITERATURE REVIEW

Why do we age? Why must a process of miraculous development, leading from a single cell to a complex, reproducing adult, inevitably culminate in a gradual decline in function, increased susceptibility to disease, and ultimately, death? The phenomenon of aging, or senescence, presents a profound puzzle for biological science. For much of human history, explanations were rooted in philosophy or vitalism. However, with the advent of Darwin's theory of evolution by natural selection, a new, scientific framework emerged—one that ironically initially struggled to explain the existence of such a seemingly maladaptive trait.

The historical development of aging theories is a story of intellectual evolution, where ideas themselves are subject to a process of variation, selection, and refinement. As Gavrilov and Gavrilova (2002) aptly note, the scientific literature on evolutionary gerontology "should be handled with great care because the significance of some publications could only be understood in the context of related studies". This article aims to provide that context, offering a comprehensive historical overview of how our understanding of aging has matured.

The central challenge for an evolutionary explanation of aging is the timing problem. Natural selection operates through differential reproductive success. Many manifestations of aging, however, occur after an organism's primary reproductive period, at ages rarely reached in the wild due to extrinsic hazards like predators, starvation, and disease. How could natural selection, which favors traits increasing fitness, possibly allow for—or even cause—a degenerative process that occurs largely after an individual has passed its genes to the next generation?

This review will navigate the historical trajectory of thought that resolved this paradox. We will explore how the field moved from Weismann's early speculations on adaptive death to the modern consensus that aging is not an adaptive program but rather a testament to the limits of natural selection's power. We will delve into the two primary non-adaptive evolutionary theories—Mutation Accumulation and Antagonistic Pleiotropy—and their supporting evidence from experimental evolution and genetics. Finally, we will examine the implications of these theories for aging research, including past missteps where evolutionary arguments were used to prematurely dismiss promising avenues of inquiry, and the exciting modern discoveries that are now challenging and refining these very theories.

2.1 Historical Development of Evolutionary Aging Theories

The logical foundations of modern evolutionary aging theories were completed only in the 1950s, nearly a century after Darwin proposed his theory of biological evolution (Darwin 1859). This delay occurred because aging evolution was a puzzling phenomenon for classical Darwinian theory. Darwin's theory, based on random heritable variations in biological traits with subsequent natural selection for preferential reproduction, seemingly contradicted aging. From this perspective, it was difficult to understand why natural selection would lead to deleterious characteristics like aging rather than eternal youth and immortality (Gavrilov and Gavrilova 2002).

The purpose of this historical analysis is not merely to recount a sequence of ideas, but to illuminate the dynamic and often contentious process of scientific discovery. Understanding this history is crucial for students and researchers entering the field, as it provides the foundational knowledge required to interpret the abundant and sometimes contradictory modern literature on aging and longevity. This article argues that while evolutionary theories provide an indispensable framework for understanding why aging exists, they are not completed doctrines but rather a set of powerful, albeit imperfect, models that continue to evolve in the light of new empirical evidence.

This section provides foundational information on aging research, an introduction to evolutionary theories of aging, and orientation in the abundant contemporary scientific literature on evolutionary gerontology. The following four main evolutionary theories of aging are discussed: Mutation Accumulation Theory proposes that aging results from the build-up of harmful mutations that affect individuals later in life, when natural selection is weaker. Antagonistic Pleiotropy Theory suggests some genes have beneficial effects early in life but detrimental effects in old age, leading to senescence. Disposable Soma Theory argues that organisms allocate resources between reproduction and somatic maintenance, with aging arising from prioritizing reproduction over long-term repair. Programmed Death and Hyperfunction Theories, while programmed death is largely discounted, newer ideas like the hyperfunction theory posit that aging is driven by the continued action of developmental programs beyond their useful period.

A special case of antagonistic pleiotropy, the disposable soma theory developed by Thomas Kirkwood and Robin Holliday, is also examined. The theories are compared to each other and to recent experimental findings.

Tab. 1 Chronological Development of Major Evolutionary Aging Theories

Year	Theory	Proponent(s)	Core Principle	Current Status
1889	Programmed Death	August Weismann	Death programmed by selection to clear resources	Refuted
1952	Mutation Accumulation	Peter Medawar	Late-acting deleterious mutations accumulate passively	Viable
1957	Antagonistic Pleiotropy	George Williams	Genes beneficial early, harmful late in life	Viable
1977	Disposable Soma	Kirkwood & Holliday	Energy trade-off: reproduction vs. somatic maintenance	Viable (special case)

Source: Goldsmith (2004), Medawar (1952), Williams (1957), Kirkwood (1977)

Currently, the most viable evolutionary theories are mutation accumulation and antagonistic pleiotropy; these theories are not mutually exclusive and both could become part of a future unifying theory of aging (Gavrilov and Gavrilova 2002).

Evolutionary theories of aging are useful because they open new avenues for further research by offering testable predictions, but they have also been harmful in the past when used to impose restrictions on aging research. Presently, evolutionary theories of aging are not fully completed but rather a set of ideas that themselves require further development and validation.

The MA, AP, and DS theories are generally considered complementary rather than mutually exclusive, and mechanisms from both MA and AP may operate simultaneously. They all provide a plausible explanation of the aging process by integrating natural selection as a main cause.

The unifying concept among the three is the idea that the intensity of natural selection decreases with chronological age. Since the probability of an individual reproducing peaks in young adulthood and then declines, selection becomes progressively less effective at weeding out defects that manifest later in life.

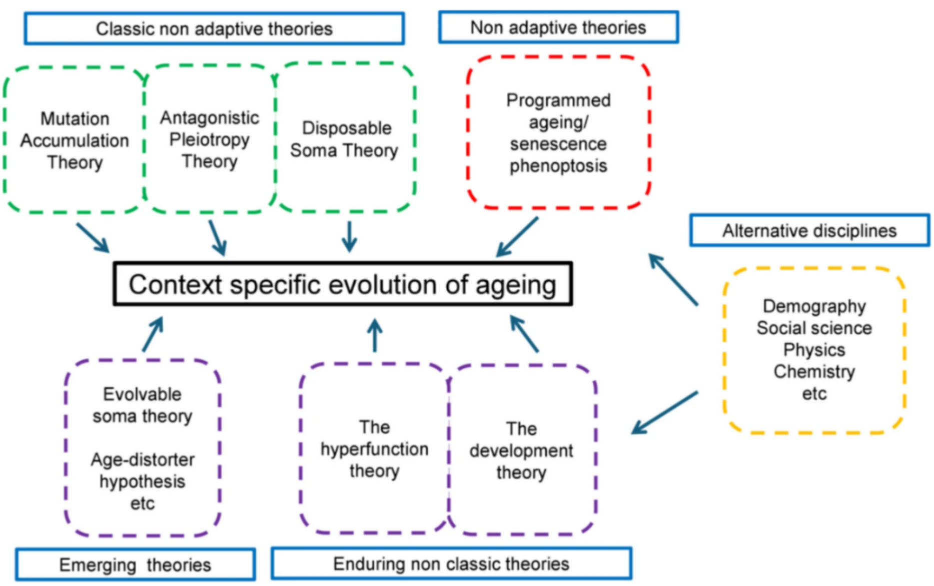
Tab. 2 Comparison of Classic Evolutionary Theories

Theory	Core Premise/Cause of Aging	Mechanism	Role of Genes	Relationship to Trade-offs
Mutation Accumulation (MA)	Natural selection declines with age, neglecting later-life deterioration	Passive accumulation of late-acting deleterious mutations	Genes with negative effects at old age accumulate passively	A trade-off is not mandatory
Antagonistic Pleiotropy (AP)	Selection favors traits beneficial in youth, even if they are harmful later in life	Active selection for pleiotropic genes (beneficial early, detrimental late)	Genes with negative effects at old age are actively kept in the gene pool	Aging is a direct consequence of a trade-off between early vigor/reproduction and later longevity
Disposable Soma (DS)	Energy is strategically partitioned for reproduction, sacrificing indefinite somatic maintenance	Insufficient investment in somatic maintenance and repair leads to cumulative damage	Longevity assurance genes control maintenance levels, optimized based on extrinsic hazards	Aging is a direct consequence of the resource allocation trade-off between maintenance and reproduction

Source: own

On Fig 1 is shown a pluralistic framework of evolution of ageing. Within this framework it is acknowledged that different models are appropriate for different taxa and depend on the ecological context. This version of pluralism also recognises the important role other disciplines, including physics and social science can contribute to our understanding of ageing.

Fig. 1



Source: The evolution of ageing: classic theories and emerging ideas

2.2 Basic Concepts of Human Longevity

Longevity serves as a general term encompassing various measures of life length, specifically including the maximum observed lifespan (highest verified age at death), maximum potential lifespan (theoretical highest attainable age), and mean lifespan (life expectancy). Historically, biological aging research, guided by the question "Why do we grow old?", focused on physiological deterioration (senescence), which is a non-adaptive byproduct of evolution. In contrast, the study of longevity asks the complementary question, "Why do we live as long as we do?" (Sacher 1978). Longevity is regarded as an evolved life-history trait resulting from positive natural selection.

There is growing interest in the topic of aging and the search for a general theory that can explain what aging is and why and how it occurs. There is also a need for a general theoretical framework that can enable researchers to cope with the enormous amount of diverse observations related to aging phenomena. Empirical observations on aging have become so numerous and abundant that a special encyclopedia, The Macmillan Encyclopedia of Aging, is now needed to even partially cover the accumulated facts (Ekerdt 2002).

The molecular hallmarks that have been the focus of recent research include: Genomic Instability and Telomere Attrition, Epigenetic Alterations and Loss of Proteostasis (breakdown of protein quality control), Deregulated Nutrient Sensing and Mitochondrial Dysfunction, and Cellular Senescence (cells cease dividing and secrete detrimental molecules) (Tenchov 2023).

Research into these hallmarks seeks to translate the evolutionary 'why' into therapeutic 'how-to' by targeting key regulatory pathways, such as those related to stress response and nutrient sensing, which are intrinsically linked to the DS trade-off.

2.3 Revolutionary Discoveries in Longevity Extension

Recent lifespan-extending mutation discoveries are remarkable. A single-gene mutation (daf-2) more than doubles nematode lifespan while maintaining activity, full fertility (contrary to disposable soma theory predictions), and normal metabolic rates (Friedman and Johnson 1988). Another single-gene mutation, methuselah, extends Drosophila mean lifespan by approximately 35% while increasing resistance to various stress forms including starvation, high temperature, and toxic chemicals (Lin et al. 1998). Another study finds out that fat-specific insulin receptor knockout FIRKO, discovered in mice, is extending lifespan by 14-18% while also increasing toxic chemical resistance (Blüher et al. 2003). The 2009 study (Harrison et al., published in Nature) was a landmark in aging research because it provided the first evidence that pharmacological inhibition of the mTOR pathway with rapamycin could extend both median and maximal lifespan in a mammal (genetically heterogeneous mice), increasing survival by 9–14% in males and females even when treatment began late in life (at approximately 600 days old, equivalent to approximately 60 human years).

Tab. 3 Major Single-Gene Lifespan Extension Discoveries

Gene/Mutation	Organism	Extension (%)	Additional Benefits	Year
daf-2	C. elegans	>100	Maintained fertility, normal metabolism	1988
Methuselah	D. melanogaster	35	Stress resistance, starvation tolerance	1998
FIRKO	Mus musculus	18	Chemical toxin resistance	2003
Rapamycin treatment	Mus musculus	9-14	mTOR pathway inhibition	2009

Source: own

A study investigated morning cortisol levels in hereditary longevity and the association of these levels with perceived age. It was found that offspring and the normal group had similar cortisol levels. On the other hand, in the normal group, an increase in cortisol levels was associated with a 0.42-year increase in perceived age. However, this was not observed in the offspring, suggesting that these descendants have a phenotype more resistant to stress (Noordam et al. 2012).

Telomeres shorten with each DNA replication and are considered a marker of cellular aging. Shorter telomeres are associated with a weaker immune system and greater vulnerability to related diseases. The two most important subunits of telomeres (TERC and TERT) were studied in relation to both telomere length and human longevity. It was found that the A allele of TERC is associated with telomere length, as are SNPs or haplotypes of TERT, which are also associated with human longevity (Soerensen et al. 2012).

Recently, the increase in life expectancy in developed countries occurs mainly after retirement age, as the mortality rate at that stage no longer increases exponentially; in fact, there are increasing indicators of stagnation or even a decline in the mortality rate at advanced ages. This evolution of mortality is not easily explained by traditional factors, such as advances in medicine or increased income, and currently constitutes a biological question, since the evolution of life expectancy among humans is far greater than that of other, much smaller beings in laboratory settings (Burger et al. 2012).

However, these scientists recognize that not all answers lie in exogenous factors, showing interest in genetics. They sought to discover a gene in the genome of centenarians that would explain the absence of disease. Currently, the FOXO3A gene is known. Regarding this, "people who have two copies of this variant in their genetic material have three times the likelihood of reaching 100 years than those who do not" (Willcox et al., 2008). Additionally, some indicate that it is necessary to study blood because high levels of HDL or "good cholesterol" have been found in long-lived people (Wang et al. 2018).

Researchers involved in these studies came to the following conclusion: "The field of aging research has been completely transformed in the past decade. When single genes are changed, animals that should be old stay young. In humans, these mutants would be analogous to a ninety year old who looks and feels forty-five. On this basis we begin to think of ageing as a disease that can be cured, or at least postponed. The field of ageing is beginning to explode, because so many are so excited about the prospect of searching for—and finding—the causes of ageing, and maybe even the fountain of youth itself." (Guarente and Kenyon 2000)

These discoveries challenged decades of evolutionary dogma. For fifty years, the search for large lifespan-extending mutations was considered futile due to evolutionary arguments. George Williams argued that "natural selection will always be in greatest opposition to the decline of the most senescence-prone system" and therefore: "Senescence should always be a generalized deterioration, and never due largely to changes in a single system... This conclusion banishes the 'fountain of youth' to the limbo of scientific impossibilities" (Williams 1957). The discovery of single-gene mutants with profoundly extended lifespan contradicts these predictions, demonstrating that evolutionary theories, while useful for generating testable predictions, should never impose constraints on aging research.

3. CONTEMPORARY LONGEVITY PHILOSOPHIES AND MOVEMENTS

Since ancient times, life extension theories have attracted diverse groups, establishing philosophical movements with different perspectives on how and to what extent human life can be extended. These movements represent approaches ranging from radical immortalism to conservative bioethical positions. The following sections examine seven major philosophical directions: immortalism, radical longevity, transhumanism, longevism, posthumanism, singularity, and bioconservatism.

3.1 Immortalism

Immoralism is a philosophical stance that challenges conventional moral values and questions whether traditional moral systems promote human flourishing. Nietzsche is often associated with immoralism because he argued that dominant moral codes, especially those rooted in Christian morality, suppress individual excellence and creativity (Nietzsche 2007). From this perspective, morality is not an objective truth but a human invention shaped by historical power dynamics.

Immoralists claim that moral norms frequently serve the interests of the majority at the expense of exceptional individuals. They also argue that moral rules can inhibit personal autonomy by prescribing rigid standards of behavior. Rather than adhering to inherited moral systems, immoralism encourages individuals to create their own values. This value-creation is seen as a process of self-overcoming and self-realization.

Critics contend that immoralism risks promoting harmful behavior by rejecting shared ethical constraints. Supporters respond that immoralism does not endorse cruelty but instead calls for honesty about the origins and limits of moral norms. Ultimately, immoralism invites individuals to critically examine moral assumptions and consider whether they genuinely support human growth.

3.2 Radical Longevity

Radical longevists believe that it is possible to extend human life by decades or even centuries through innovations in genetics, biomedicine, nanotechnology, and other fields of science. They focus on overcoming the biological limitations of aging and emphasize optimizing health to achieve "practical immortality." Many of them are optimistic about the future of medical technologies and believe that aging can be "cured" as a disease.

Part of the theories widely advocated by proponents of radical longevism are described in the book The Longevity Paradox by Dr. Steven Gundry. In The Longevity Paradox, the author, a renowned cardiologist and longevity researcher, challenges conventional wisdom about aging. He argues that aging is not an inevitable process leading to diseases and infirmity; instead, it is a disease that can be prevented or reversed. According to Gundry, modern medicine usually focuses on treating diseases after they occur, but a proactive approach to longevity can slow, prevent, or even reverse the aging process (Gundry 2019).

Dr. Gundry explains the concept of "healthspan"—the period of life during which a person not only lives longer but is also free from chronic diseases. He emphasizes that the goal should be to extend healthspan, not just lifespan. To achieve this, we must understand the mechanisms that lead to aging and through them improve quality of life as we age.

The "longevity paradox," as Gundry calls it, is the idea that foods we think are healthy—like lean meat, grains, and legumes—are actually harmful to the microbiome. Many of these foods contain lectins—plant proteins that can damage the intestinal lining, cause inflammation, and contribute to the development of diseases. Gundry claims that lectins are one of the main culprits for many chronic diseases and accelerated aging.

To address this, Gundry recommends a diet that avoids high-lectin foods. This includes common foods like wheat, beans, tomatoes, and potatoes. He recommends a diet based on vegetables, fruits, nuts, seeds, and healthy fats, especially olive oil and avocados, which support the microbiome and reduce inflammation. He also emphasizes the benefits of intermittent fasting, which has shown positive effects on longevity.

Gundry outlines seven key principles or "paradoxes" that lead to radical longevity. They include diet, exercise, stress management, sleep, and other lifestyle factors that can have a serious impact on aging: avoiding lectins, fasting and eating in a specific time window, optimizing gut health, exercise and muscle mass, sufficient sleep, stress management, and living with purpose.

3.3 Transhumanism

Transhumanists believe that technologies will allow humanity to go beyond its biological limitations and create hybrid forms of human existence that include machine or cybernetic parts. In the context of extending life, transhumanists are interested in implementing cybernetic implants, genetic modifications, and artificial organs that can extend life and improve quality of existence.

The book "The Transhumanist Manifesto" is a key document in the transhumanist movement, signed by leading philosophers and scientists such as Nick Bostrom, David Pearce, Raymond Kurzweil, Max More, and others. The manifesto expresses the vision for the future of humanity through the development of scientific and technological innovations that can improve the physical and mental capabilities of humans. The manifesto advocates the idea that humanity can and should use new technologies to overcome the limitations imposed by biological evolution, including diseases, aging, and death (Vita-More 2020).

Transhumanism is based on the belief that human progress can be accelerated through innovations in genetics, nanotechnology, robotics, and artificial intelligence. This leads to the possibility of radically extending life, improving and the evolution of humanity. The basic message of the manifesto is that humanity must take an active role in shaping its future and overcoming the natural limitations of human biology. Instead of resigning to our biological heritage, we should strive to transform ourselves through technologies.

Transhumanists believe that with the help of new technologies, people can improve mental and physical capabilities. Artificial intelligence, cognitive prosthetics, and neurological technologies can lead to significant increases in intellectual capabilities. For example, through implants and interfaces with the brain, memory, thinking ability, and learning potential can be improved.

At the same time, physical capabilities can be improved through biotechnologies, genetic manipulations, and bionic bodies. This will make it possible not only to extend life but also to improve its quality, as physical limitations like weakness and frailty associated with aging will be eliminated.

Transhumanism strives for a world without diseases and suffering. Through medical innovations, including gene engineering and nanotechnology, treatments will be created that will eliminate diseases like cancer, cardiovascular diseases, and other chronic diseases that are now major causes of death.

The manifesto emphasizes the global perspective of transhumanism. The idea is that advances in science and technology can be used to achieve global prosperity by reducing poverty and global disparities. This is possible through providing more accessible and effective health care, education, and technologies for all people around the world.

Transhumanists are aware of the ethical dilemmas that may arise from the use of new technologies for transformation. Issues of equality, accessibility of technologies, as well as the dangers of their unlimited use, are important topics in the manifesto.

The ethical use of technologies for human transformation requires global regulation and careful planning.

One of the main concerns is how social and economic inequality will hinder access to these technologies. If only the rich have access to life-extension technologies or cognitive enhancements, it could increase social disparities and create new forms of inequality.

Transhumanism does not deny the potential dangers associated with the rapid development of technologies. One of the main fears is that technologies can be misused or improperly used by various political or economic groups. For example, the possibility of manipulations with genetic code or creating superhumans who have significant superiority over ordinary people can lead to new forms of totalitarianism and global conflicts.

Technologies for human enhancement, such as genetic modifications or creating bionic forms, can put humanity before new moral and philosophical questions. What does it mean to be "human" if the biological form can be changed or replaced? These questions place transhumanism in the context of major ethical challenges.

Transhumanism offers a radical view of the future of humanity, providing a path to new possibilities for physical and mental enhancement. Through new technologies, humanity can achieve a longer and healthier life, free from diseases and suffering, and expand the boundaries of intellectual capabilities.

Despite these positive perspectives, transhumanism faces ethical, social, and political challenges. The future of transhumanism will depend on humanity's ability to manage these new technologies responsibly and fairly. To be successful, transhumanism must ensure that progress will be accessible to all people and will not lead to new forms of inequality and abuses.

In conclusion, "The Transhumanist Manifesto" envisions a future in which human evolution will be not only a natural process but also a result of human intervention in science and technology, and it emphasizes that this process must be managed wisely and ethically to avoid potential risks.

Another key work in transhumanism is "The Ethics of Human Enhancement" . The authors examine the concept of the future in which technologies will allow the creation of "brain machines" and even the possibility of uploading human consciousness into computer systems (Clarke, S. et al. (2016). This idea of "copying" consciousness and transferring the conscious process to machines is known as consciousness 2.0. Bostrom argues that humanity is on the threshold of creating superintelligent machines that will have the ability to think and feel like humans but with the possibility of significant superiority in terms of intellect and processing speed (Bostrom,2007)

Bostrom categorizes the different forms of enhancement into three main directions: physical, psychological, and cognitive enhancements. Each of these types of enhancements brings its own ethical issues.

1. Physical Enhancements: This includes genetic manipulations, bionic implants, organs, artificial limbs, and other technologies that can increase a person's physical capabilities. Questions like whether people should be allowed to change their bodies to achieve the ideal physical form are basic ethical themes in this context.

2. Psychological Enhancements: This includes modifications that can improve the emotional and psychological resilience of the individual, such as eliminating depression, stress, or negative emotions.

3. Cognitive Enhancements: This includes increasing intellectual capabilities through implants, gene engineering, or other cognitive technologies.

Bostrom's main question is whether there are moral boundaries for human enhancements. While enhancement technologies offer unlimited possibilities, they pose a number of ethical questions regarding risks and consequences.

Bostrom insists that to ensure ethical development of enhancement technologies, clearly defined boundaries and regulation must be set. This includes both scientific and ethical efforts to prevent abuses and protect social justice. Technologies must be managed so that they are accessible to all, without creating new forms of inequality or discrimination.

3.4 Longevism (Longevity)

The term longevitism describes the philosophical, scientific, and social movement dedicated to significantly extending the healthy human lifespan. It is characterized by a shift in focus from merely extending lifespan (the total years lived) to maximizing healthspan (the years lived in good health). Scientific longevitism is grounded in the understanding of the hallmarks of aging and the development of targeted interventions to modulate these processes. This includes pharmacological approaches (e.g., senolytics, mTOR inhibitors), genetic engineering, and lifestyle modifications. The ultimate goal is to compress morbidity—to ensure that the period of age-related illness and frailty is minimized and occurs only at the very end of a much longer life. The concept is often divided into two main schools of thought: moderate longevitism, which focuses on incremental healthspan extension through conventional medical and lifestyle means, and radical longevitism, which seeks a fundamental, potentially indefinite, extension of human life.

Longevists generally focus on scientific approaches and biomedical technologies for extending life but without going to the extremes of immortalism. They believe that we can extend human life by decades if scientific discoveries in areas like gene engineering, nanotechnology, therapies, etc., are applied correctly and ethically. Longevists often support the principle of health optimization and actively explore new methods for preventing age-related diseases.

3.5 Posthumanism

It is related to the idea that the human form and consciousness can be transformed through technologies. Posthuman theories include philosophical perceptions of life after human evolution, including ideas for immortality through a combination of biological, mechanical, and technological elements. Posthumanism often focuses on overcoming the physical and mental limitations of the human body and consciousness through technologies like neuroprosthetics and "consciousness uploading".

This is well described in the book Homo Deus: A Brief History of Tomorrow by Yuval Noah Harari . He expands the scope of his previous book Sapiens, in which he examines the past of humanity, by moving to the future and the possibilities that open up for humans in the context of technologies, biology, and philosophy. In this book, Harari examines how human nature changes with advances in technologies and science and offers predictions for the future of humanity.

The main thesis of Homo Deus is that modern humans no longer strive only for survival and solving basic life problems like hunger, diseases, and wars but instead begin to focus on new goals like achieving unlimited happiness, immortality, and the possibility of superiority over nature. Harari describes these new aspirations as part of the Homo Deus project - the pursuit of transforming humans into gods or beings that will have the power to control the very nature of life and death.

Harari questions the role of humans in the world, noting that with the development of science and technologies, human civilization has managed to cope with major problems that were main causes of suffering in the past. As a result, humanity begins to concentrate on new goals that encompass biological enhancements and achieving eternal life.

1. Happiness: Harari explores how new technologies, like genetics, neuropsychology, and artificial intelligence, can help us manage our emotions, eliminate fear and depression, and achieve perfect mental health.

2. Immortality: The possibility of extending life through biotechnologies and gene engineering is considered a key goal of the future. Harari speaks of the possibility of overcoming the natural process of aging and simultaneously controlling mortality through genetic and medical innovations.

3. Transcendence and Divine State: There exists a striving for overcoming physical and cognitive limitations of humans through technologies that increase intellect and allow us to become beings with almost divine capabilities. Harari examines the possibility of merging humans with technologies, creating hybrids between biological and non-biological.

Harari dedicates significant attention to the possibilities and risks that new technologies bring for the future of humanity. Particular attention is given to the possibility of creating superintelligent machines and artificial intelligence that can radically change social structures and daily life. These technologies can lead to deep social divisions and inequalities between those who have access to new technologies and those who do not.

One of the big questions Harari poses is whether humans should continue to strive for achieving technological "divine powers." The book poses questions about the ethics of gene engineering, cloning, and creating synthetic organisms. Harari not only describes the possibilities that these technologies provide but also questions their ethical justification.

Harari concludes the book with reflections on the future of humanity in the context of global risks accompanying technological innovations. Humanity can reach a point where new technologies and artificial intelligence will be controlled by a small group of people or corporations, which will lead to new forms of inequality and social injustice.

Harari also speaks of the possibility of destroying humanity through new technological discoveries, such as biological weapons or artificial intelligent systems that can go out of control. These risks will shape the future of humanity.

In conclusion, Yuval Noah Harari in Homo Deus presents his vision for the future of humanity, in which artificial intelligence, biotechnologies, and nanotechnologies will merge and lead to a stage of development where technologies will become so powerful that they will surpass human capabilities. This process will lead to singularity — a moment when all biological and physical limitations will be overcome, and humanity will transition to a new phase of existence. Harari not only predicts but also justifies this idea with scientific facts and forecasts that herald radical transformations of society and humanity itself.

3.6 Singularity

Among followers of the theory of technological singularity, it is believed that with significant advances in artificial intelligence and nanotechnology, humanity will achieve a technological point where progress will become unmanageable and lead to radical changes in life and the possibility of extending life. Singularity predicts that after this point, we will be able to control the processes of aging and diseases through artificial intelligence and self-regulating technologies, which can lead to significantly extending life.

This is well described in the book "The Singularity is Near: When Humans Transcend Biology" by Ray Kurzweil. The book is one of the most important books related to the concept of technological singularity. Ray Kurzweil — inventor, futurist, and theorist of technological progress, the book examines how humanity will reach a point where technologies will begin to develop at an exponential rate and will surpass human capabilities. Singularity, as defined by Kurzweil, is the moment when artificial intelligence (AI) and other technologies will be able to perform self-improvement, leading to irreversible and fundamental changes in society and human existence.

In his book, Kurzweil analyzes the acceleration of technologies that will create new possibilities for overcoming the biological limitations of the human body and consciousness. These changes will lead to stages of evolutionary transformations in which humans and machines will merge in ways we cannot imagine at present.

Kurzweil begins by examining the principle of exponential technological progress. He argues that technologies do not develop linearly but exponentially, meaning that at each new stage, progress increases at a rate faster than the previous one. Technologies for information processing, starting from the simplest calculations at the beginning of the computer era, will reach levels of complexity that will challenge radical and social transformations.

Kurzweil claims that the human consciousness can be emulated and transferred to digital form. This will lead to a new stage in the development of civilization, where people will exist as digital beings in virtual environments, rather than as biological organisms.

Kurzweil examines the technologies that would allow uploading human consciousness to machines. These technologies include neuroscience, brain implants, nanotechnology, and quantum computers. According to him, with advances in these fields, it is possible in the future to create systems that will imitate human consciousness and expand cognitive capabilities to unlimited levels.

Kurzweil discusses how these brain machines will change society and allow people to connect with each other in new ways. For example, through virtual consciousness, people will be able to exist in fully virtual realities or even take advantage of practically unlimited lifespan.

Like Harari in Homo Deus, Kurzweil poses questions about the ethics and social consequences of such development. The possibility of uploading consciousness and existing in digital form raises questions about identity, rights of digital beings, and social justice. If only part of humanity has access to these technologies, new forms of social inequalities may emerge.

Kurzweil also examines how these technologies will change the ways in which people perceive time, existence, and relationships. The possibility to "live" in digital form, with eternal life and constant intellectual advancement, can lead to deep philosophical and psychological dilemmas.

In conclusion, Kurzweil predicts that the creation of brain machines will open new possibilities for human evolution. Humanity will transition to a new civilization in which machines and humans will exist not only in parallel but will merge into new forms of existence. Technologies that can transform our consciousness will also change the very perception of human essence.

Kurzweil does not avoid posing the questions about possible risks and dangers associated with these technologies, such as the possibility of control by small elites and the disappearance of ethics in the future world.

3.7 Bioconservatism

Bioconservatives are not so focused on extending life but are concerned about the potential ethical, social, and biological consequences of radical efforts to extend life. They oppose excessive intervention in the biological process of aging and believe that technologies can cause undesirable consequences, such as social and economic inequalities or ethical problems related to manipulating the human body and mind. All these directions have different viewpoints regarding what longevity represents, what technologies and scientific approaches can help extend life, and what ethical issues might arise along the way. Some of these currents aim for the possibility of immortality, while others focus more on reasonable and ethical frames. Only time will show which path humanity will take and to what extent evolution will be influenced by technologies.

Table 4: Comparative Analysis of Longevity Philosophies

Philosophy	Primary Goal	Methods	Timeline	Ethical Concerns
Immortalism	Achieve immortality	Mind uploading, digital consciousness	50+ years	Identity preservation
Radical Longevity	Century-scale lifespan	Genetics, biomedicine, lifestyle	10-30 years	Access inequality
Transhumanism	Transcend biology	Cybernetics, AI integration	30-50 years	Human nature alteration
Longevism	Decades extension	Gene therapy, nanotechnology	5-20 years	Safety, efficacy
Bioconservatism	Caution, limits	Regulation, ethical frameworks	Ongoing	Unintended

Source: own

As Max More and Natasha Vita-More have observed, although the transhumanists of the late 1980s and early 1990s were predominantly engaged in the examination and endorsement of novel modalities of technological metamorphosis, by the onset of the new millennium, the viability of “nano-bio-info-cogno-technologies” (NBIC) emerged as a more broadly recognized possibility. Accompanying this transformation, the emphasis of transhumanist philosophy also transitioned towards the prospective detriments and governance of these biotechnologies (More, M., & Vita-More, N. (2013).

For Habermas, the initial premise in the discourse regarding biotechnologies in the early twenty-first century is characterized by a newfound consciousness of an evolving condition wherein the domain of what has traditionally been considered "given" to humanity transitions towards "the domain of artifacts and their production." In other terms, the distinction between the organically constituted and the technologically fabricated increasingly becomes indistinct (Sandel, M. J. (2007). At the core of this discourse lies the differentiation between medically oriented therapeutic interventions and those aimed at human enhancement.

An applied example of the comprehensive study of a person is the famous case of Jeanne Louise Calment, a woman who until very recently was known as the longest-lived person in history, reaching 122 years and 164 days. However, in December 2018, Nikolai Zak published a study about her and expressed suspicions that she was not actually the longest-lived woman in the world, and that it was her daughter, Yvonne, who assumed her identity to avoid paying taxes, which would imply that Yvonne Calment died in 1997 at 99 years old and not

The island of Okinawa (Japan) attracted the interest of scientists and demographers for having the longest-lived people in the world. Researchers Suzuki, Willcox, & Willcox (2005), from a biopsychosocial approach, were interested in the diet, physical practices, social and spiritual customs, among other factors that might explain the exemplary health of the island’s inhabitants. In the book “The Okinawa Diet Plan,” they explain the characteristics of the Japanese diet: drinking plenty of water and infusions without milk or sweeteners, calcium, a weekly portion of red meat, eggs, soy, fish, rice, fruits, vegetables… (Willcox, Willcox, & Suzuki, The Okinawa Program, 2001; Suzuki, Willcox, & Willcox, 2005).

More recently, Dan Buettner (2015), a National Geographic reporter, discovered the five regions where the longest-lived people in the world are found, which he calls “Blue Zones”: the island of Sardinia (Italy), the island of Okinawa (Japan), Loma Linda (California), Nicoya Peninsula (Costa Rica), and Ikaria (Greece). The research team found lifestyle characteristics they shared, which they called Power9. Among these biopsychosocial habits are: moving through nature by cultivating and foregoing mechanical conveniences, having a “life plan,” dedicating time to oneself to reduce stress by remembering ancestors, praying, or taking a nap, stopping eating when the stomach is 80% full, a propensity/inclination toward organic farming, moderate alcohol consumption, spirituality, and maintaining a sense of community and family close to home (Buettner & Skemp, 2015).

4. DISCUSSIONS

Regarding the biological aspect, numerous studies have been conducted over the past 10 years on the presence of genes that benefit or impair longevity, as well as on telomeres, its length and why it is affected. Recently, it has been discovered that the apparent heritability of longevity may be due to selective mating among long-lived individuals.

Some of these biological factors exhibit potentially modifiable aspects, for example, telomere length or cortisol levels, through possible psychosocial interventions such as smoking behavior, loneliness, social support, emotional intelligence, and mind-wandering cognition.

In addition to this biological plasticity, the present and future right of the population to know whether their genetic record contains the aforementioned genes and variations is proposed. Also, to allow individuals who have experienced traumatic events to undergo testing to determine their telomere length. All of this aims to enable early intervention in those presenting a higher risk of morbidity and mortality.

Regarding psychological outcomes, factors also emerge that appear suitable for beneficial transformation of long-lived developmental trajectories: coping strategies, resilience, capacity for forgiveness, awareness, among others previously mentioned. These foundations of psychological functioning begin to form in childhood, highlighting the importance of employing well-established parental educational styles (Baumrind, 1971) that reinforce these factors, such as the democratic style characterized by high affection and high control. Consequently, new research is proposed to correlate the different educational styles received during childhood and adolescence (democratic, permissive, authoritarian, and neglectful) with long-lived developmental outcomes.

In the social domain, the influence of veganism as a lifestyle in our current population could be a topic of interest for future research. This would challenge the notion of a “balanced diet,” which includes the consumption of all food groups and has been commonly accepted since childhood. On the other hand, research on the effects of caloric restriction in humans—still scarce and novel (Redman et al., 2018)—presents very promising results. Therefore, further investigation into this diet and its relationship with reduced probabilities of developing certain diseases associated with adulthood and aging, such as diabetes, osteoporosis, and even degenerative diseases like Alzheimer’s and Parkinson’s (Walford, 2000), is warranted.

Advances in healthcare technologies have improved the assessment and diagnosis of diseases, optimizing patient treatment and directly contributing to increased life expectancy. However, other types of technologies (UVA rays, mobile radiation, portable devices, tablets, etc.) are commonly believed to be harmful to health. Yet, their medium- and long-term effects and potential influence on human lifespan have not been thoroughly studied.

Regarding limitations in information retrieval, many studies are based on specific populations, meaning that their data cannot be generalized, which complicates obtaining information applicable worldwide.

5. CONCLUSION

The historical journey of aging theories is a compelling narrative of scientific progress. It began with Weismann's bold but incorrect hypothesis of programmed death, which was valuable more for the debate it sparked and the cellular mechanism it predicted than for its core premise. The field then matured with the dual pillars of the modern evolutionary theory of aging: Medawar's Mutation Accumulation and Williams' Antagonistic Pleiotropy. These theories successfully resolved the timing paradox, explaining aging as a non-adaptive consequence of the declining force of natural selection, either through passive genetic drift or active selection for early-life benefits.

The subsequent development of the Disposable Soma Theory provided a specific and powerful energetic framework for understanding antagonistic pleiotropy. Experimental work in fruit flies, nematodes, and other species has largely supported the existence of trade-offs between reproduction and longevity, a cornerstone of the evolutionary view.

However, history has also taught a crucial lesson in scientific humility. The same evolutionary theories that provide a powerful explanatory framework can, when applied dogmatically, become stifling ideologies that hinder discovery. The unexpected finding of single-gene longevity mutations serves as a stark reminder that biological reality is often more complex and surprising than our models. As Gavrilov and Gavrilova conclude, and as the title of a contemporary review warns, "Evolutionary theories of aging: handle with care" (Bourg, 1998).

Will the increase in longevity (and the consequent aging of the population) slow down, or even reverse, at some point, or will it continue forever, or at least for the next few centuries? It is well known that nothing is more difficult to predict than the future. However, there are clear indications that the increase in longevity will be a permanent process that will continue indefinitely, although perhaps with periods of slowing down in the future. This assessment is derived from trends in life expectancy (and in the global fertility rate). In the case of wealthier countries, this trend may be mitigated or even, in some cases, reversed due to immigration from poorer regions.

These theories are most useful when they open new avenues for research by suggesting testable predictions. They are least useful when used to impose a priori limitations on what is possible. As we move forward, the integration of evolutionary ultimate causes with mechanistic proximate causes—from genetics and cell biology to systems-level reliability models—will be essential for developing a truly unifying theory of aging and longevity. The history of this field is not a closed book but an ongoing story, with each new discovery adding a chapter to our understanding of life's most universal process.

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