

Review

Biological Aging Acceleration Due to Environmental Exposures: An Exciting New Direction in Toxicogenomics Research

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Abstract: Biological clock technologies are designed to assess the acceleration of biological age (B-age) in diverse cell types, offering a distinctive opportunity in toxicogenomic research to explore the impact of environmental stressors, social challenges, and unhealthy lifestyles on health impairment. These clocks also play a role in identifying factors that can hinder aging and promote a healthy lifestyle. Over the past decade, researchers in epigenetics have developed testing methods that predict the chronological and biological age of organisms. These methods rely on assessing DNA methylation (DNAm) levels at specific CpG sites, RNA levels, and various biomolecules across multiple cell types, tissues, and entire organisms. Commonly known as “biological clocks” (B-clocks), these estimators hold promise for gaining deeper insights into the pathways contributing to the development of age-related disorders. They also provide a foundation for devising biomedical or social interventions to prevent, reverse, or mitigate these disorders. This review article provides a concise overview of various epigenetic clocks and explores their susceptibility to environmental stressors.

Keywords: biological clocks; epigenetic clocks; toxicology; toxicogenomics; DNA methylation



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1. Introduction

Everyone ages, but biologically not at the same pace. Aging is quantified based on two parameters—chronological age (C-age) is the amount of time that has elapsed from birth to a given date, and biological age (B-age) is the measure of the apparent age of an organ or tissue based on several factors discussed in this review. Individuals with the same C-age can have different health status, and therefore C-age offers limited information regarding the biological pathways underlying aging [1]. That led to the development of the concept of “biological age” which can accurately reflect phenotypic characteristics such as “functional frailty” and molecular level markers such as DNAm [2–5]. Over the past decade, aging has become a critical public health concern because of several socio-economic implications [6]. The unprecedented increase in world’s aging population will continue to rise globally in the next few decades and by 2050, the number of people aged 60 and older would reach 21% [7]. This varies from 9.3% in Africa (low) to 36.5% in Japan (high) and 21.4% in the USA in 2050 [8]. After adolescent growth and development, there is a progressive decline in tissue and organ function along with an exponential rise in mortality rates, doubling roughly every 7–8 years after puberty [9]. The prevalence of significant chronic conditions, such as cardiovascular disease, cancer, diabetes, and Alzheimer’s disease, increases exponentially as individuals age [6]. This is primarily caused by a progressive gradual accumulation

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Table of Contents Review Of Biological Research In Aging Vol

1. Understanding the eBook Review Of Biological Research In Aging Vol
 - The Rise of Digital Reading Review Of Biological Research In Aging Vol
 - Advantages of eBooks Over Traditional Books
2. Identifying Review Of Biological Research In Aging Vol
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Review Of Biological Research In Aging Vol
 - User-Friendly Interface
4. Exploring eBook Recommendations from Review Of Biological Research In Aging Vol

- Personalized Recommendations
- Review Of Biological Research In Aging Vol User Reviews and Ratings
- Review Of Biological Research In Aging Vol and Bestseller Lists
- 5. Accessing Review Of Biological Research In Aging Vol Free and Paid eBooks
 - Review Of Biological Research In Aging Vol Public Domain eBooks
 - Review Of Biological Research In Aging Vol eBook Subscription Services
 - Review Of Biological Research In Aging Vol Budget-Friendly Options
- 6. Navigating Review Of Biological Research In Aging Vol eBook Formats
 - ePub, PDF, MOBI, and More
 - Review Of Biological Research In Aging Vol Compatibility with Devices
 - Review Of Biological Research In Aging Vol Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Review Of Biological Research In Aging Vol
 - Highlighting and Note-Taking Review Of Biological Research In Aging Vol
 - Interactive Elements Review Of Biological Research In Aging Vol
- 8. Staying Engaged with Review Of Biological Research In Aging Vol
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Review Of Biological Research In Aging Vol
- 9. Balancing eBooks and Physical Books Review Of Biological Research In Aging Vol
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Review Of Biological Research In Aging Vol
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Review Of Biological Research In Aging Vol
 - Setting Reading Goals Review Of Biological Research In Aging Vol
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Review Of Biological Research In Aging Vol

- Fact-Checking eBook Content of Review Of Biological Research In Aging Vol
- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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