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THE ROLE OF PHYSIOLOGY IN THE FORMATION OF GERONTOLOGY

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Abstract

This article analyzes the role of physiology in the formation of gerontology. The study addresses human aging processes, the functional characteristics of physiological systems, and their age-related changes. It demonstrates that theoretical and applied knowledge in physiology constitutes the principal scientific foundation for the development of gerontology, playing a crucial role in investigating aging processes, preventing disease, and formulating key recommendations aimed at increasing life expectancy. In addition, the article provides a scientific rationale for the role of physiological knowledge in gerontology in promoting a healthy lifestyle, proper nutrition, physical activity, and psychological stability.

Keywords: gerontology, physiology, aging process, healthy lifestyle, human health, body systems, life expectancy, physical activity, psychological stability.

Introduction

Revolutionary changes in biology during the nineteenth century and the early twentieth century—primarily associated with the discovery of fundamental biological laws—also influenced the development of the biology of aging. The accumulation of knowledge about aging in living organisms and its generalization on the basis of newly discovered biological laws made it possible to formulate

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scientifically testable theories of aging; some of these theories also incorporated elements of a systems approach.

These theories served as a foundation for experimental research, as well as for the development and practical application of methods intended to extend life. However, the key to understanding the primary causes of aging lies in processes occurring at the molecular level of living matter. The lack of relevant knowledge hindered the emergence of reliable and comprehensive theories of aging and the development of effective therapies for age-related diseases.

On the basis of evolutionary perspectives, several theories of aging emerged. A. Weismann's theory of the immortality of unicellular organisms and of the germ cells of multicellular organisms, as well as his view of the adaptive nature of aging and death, gained broad popularity; according to this theory, older individuals compete with younger ones and reduce the reproductive potential of the population.

The views of I. I. Mechnikov were also significant. He emphasized that a trait that initially has adaptive value in the course of evolution may later become a source of harm to the organism, leading to disease and aging.

Research in biochemistry and biophysics contributed to the emergence of notions that aging results from the "exhaustion of a vital enzyme," the loss of certain chemical substances, dehydration of tissue colloids, accumulation of harmful metabolic products, and the general wear of the organism. Embryologists associated aging with the slowing of growth and with a decline in the capacity of cells to renew due to differentiation.

Neurophysiologists regarded old age as a consequence of functional disturbances in higher nervous activity. Applying early versions of systems theory to the study of aging led to the conclusion that aging is inevitable because the probability of failures arising in the functioning of a complex system is exceedingly high.

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The synthesis of demographic data, in turn, opened the way for broad use of mathematical methods to describe the aging process and provided a scientific basis for investigating the biology of lifespan.

On the basis of theoretical conceptions of aging mechanisms, attempts were initiated to develop and apply methods for prolonging life, although their effectiveness remained highly questionable. The organizational formation of gerontology also began: gerontological and geriatric scientific schools and societies emerged, specialized conferences started to be held, and periodicals devoted to problems of aging and life extension began to be published.

One such journal was *Long Life*, published by Ch. Stevens—one of the founders of American gerontology and a proponent of the idea of life extension—which released two volumes in 1895 and 1896 (Gruman, 1959; Freeman, 1979). During this period, modern terms such as *gerontology* (for the science of aging and life extension) and *geriatrics* (for the application of this knowledge in medical practice) came into use. The first term was introduced by I. I. Mechnikov in his book *Studies on the Nature of Man* (first published in French in 1903) (Metchnikoff, 1903, p. 386).

It was also during this time that the practice of constructing mathematical models—an integral element of systems analysis in gerontology—was established. In 1825, B. Gompertz proposed a functional relationship to describe population attrition (mortality), and in 1860 W. Makeham modified it. Since then, this relationship (the Gompertz–Makeham equation) has remained a cornerstone of the biology of lifespan.

Later, in the 1910s–1920s, N. A. Belov proposed an analytical model to describe aging in complex systems. The analytical descriptions of populations developed by V. Volterra and A. Lotka in the 1920s (Berkinblit & Gaaze-Rapoport, 1975) laid the groundwork for modern analytical investigations of the evolutionary dimension of the aging phenomenon at the population level.

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Early attempts to extend life based on physiological research

One of the pioneers in searching for life-extension methods grounded in evolutionary ideas about aging was the eminent Russian biologist I. I. Mechnikov (1845–1916). In his view, a trait that initially has adaptive value in evolution may later, due to side effects arising in its functioning or changes in living conditions, become a source of harm to the organism. Ultimately, this leads to disharmony in organismal functioning, disease, and aging (he distinguished between premature and normal aging). Importantly, Mechnikov understood the link between the presence of consciousness and the desire to live as long as possible. He wrote: "Among all disharmonies in human nature, the most fundamental is the inconsistency between the shortness of life and the need to live much longer." This disharmony arises because "high intellectual development has generated awareness of the inevitability of death, whereas animal nature has shortened life through chronic poisoning." Here, the term *poisons* should be understood broadly, since he believed that "natural death may also be equated with poisoning, only it occurs not through bacteria foreign to the organism, but through the elements of our own body."

A modern analogue of such self-poisoning may be oxidative damage to cells by free radicals, which is now regarded as one of the principal causes of aging; in this respect, Mechnikov's reasoning was remarkably close to what is currently considered plausible. In his view, self-poisoning arises because "the human being, produced by a long developmental cycle, carries clear traces of animal origin. Having achieved a level of intellectual development unknown in the animal world, he has nevertheless retained many traits that are not only unnecessary but directly harmful."

The life-extension method proposed by Mechnikov was closely related to his work in microbiology (Mogilevskiy, 1958). He argued that the primary source of disharmony leading to premature aging is the large intestine: originally serving to digest coarse plant food, this organ—after dietary patterns changed—became,

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as it were, an incubator for putrefactive microorganisms; their metabolic products poison the organism and shorten lifespan. Accordingly, he recommended consuming fermented milk products (yogurt and others) that suppress putrefactive bacteria. As a forward-looking approach, he even proposed surgical removal of the large intestine. However, Mechnikov did not absolutize the role of fermented milk products (especially in preventing normal aging); rather, this was part of his integrated approach to life extension, which he called *orthobiosis*—a correct way of life (Piontkovskiy, 1956). This approach was to include hygienic measures and, in the long term, changes in human nature and the social order. His foresight—like his self-poisoning hypothesis—may prove to have been accurate: one of the most probable pathways to life extension is considered to be the use of genetic engineering methods, which indeed implies "changing human nature."

Undoubtedly, both the practical and theoretical work of Mechnikov laid the foundations of modern gerontology (Frolov, 1989), shifting the study of aging beyond traditional medical-hygienic perspectives and placing it within the broad framework of evolutionary-biological research (Tishkov, 1987). However, the primary method he proposed (i.e., the use of yogurt) is unlikely to extend life substantially and in a reliably measurable way.

In the late nineteenth and early twentieth centuries, another approach to life extension involved the use of extracts from the sex glands (Grmek, 1964; Kurtsman & Gordon, 1982). This approach was based on the assumed relationship between health and sexual activity, i.e., the belief that stimulating sexual function might prolong life (notably, even Daoists reportedly added preparations derived from testes to food). Interest in this method is associated with the French physiologist Ch. Brown-Séquard (1818–1894), who—after testing on animals—self-injected an extract obtained from dog and rabbit testes and claimed to have rejuvenated by 30 years. The method began to be applied on a limited scale. Later, the Austrian surgeon O. Steinach (1861–1944) attempted

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to stimulate testicular function surgically, including through transplantation of animal testes.

The effectiveness of such methods was largely short-term, in part because they were applied in isolation rather than as components of a complex, systemic approach. Nonetheless, many of these methods contained a rational element, and research on tissue therapy (based on the phenomenon of cell activation by degradation products of cells of the same type—understandable insofar as cell death must be compensated by increased activity and/or proliferation of other cells) and hormonal therapy continues (Nikitin, 1982).

It should be noted that in our country, interest in the use of sex gland extracts evolved into serious research on the possibility of controlling aging processes; the continuation of these studies has, at present, contributed to the development of more effective methods for life extension.

During the same period, concepts began to form regarding the important role of the central nervous system in the development of many pathologies (partly as a response to R. Virchow's cellular pathology theory). The emergence of this approach is associated with the work of I. M. Sechenov, which influenced S. P. Botkin, who in turn involved I. P. Pavlov in the study of this problem (Ilinskiy, 1985). Research conducted by Pavlov himself, as well as by his students (A. V. Tonkikh, L. A. Andreeva, D. I. Soloveychik, A. D. Speranskiy, M. K. Petrova, and others), shaped the understanding of the organism as a self-regulating system and of uneven age-related changes in nervous regulation (Duplenko, 1985). M. K. Petrova (1946), summarizing many years of age-related physiological experiments conducted within the Pavlov school, concluded that the nervous system plays a leading role in the development of aging processes.

Owing to S. P. Botkin's methodological views, clinical research developed in close connection with experimental-physiological investigations into the relationship between nervous activity and pathological processes (including those related to aging). The principal proponent of this direction was the prominent

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domestic clinician G. F. Lang. Although his primary topic was hypertension (he authored the neurogenic theory of hypertensive disease), he also addressed mechanisms of atherosclerosis, diabetes mellitus, and other diseases (Lang, 1975). His student V. G. Baranov founded the Leningrad school of endocrinologists (Ilinskiy, 1985).

Another variant of activating organismal functions and, accordingly, extending life—known since the Middle Ages—was the consumption of human blood (believed to be a carrier of vital heat). At that time, there were also attempts at blood transfusion, but they were unsuccessful (Grmek, 1964). On the other hand, in the early twentieth century, a popular theory held that the immortality of unicellular organisms could be explained by their ability to undergo conjugation (genetic exchange). It was also assumed that the mobile elements of blood might likewise be capable of conjugation (Metalnikov, 1917). From this, a logical conclusion was drawn that conjugating blood cells from different people might prolong their lifespan. Research into this possibility is associated with the work of the Russian physician and philosopher (a founder of systems theory) and revolutionary A. A. Bogdanov (1873–1928) (Nagorniy, 1940; Karsaevskaya & Shatalov, 1978). Bogdanov believed that aging is caused by random disturbances in the functioning of individual organs, which weaken certain links within the organism's system. Crucially, the weakest link is most sensitive to such disturbances; therefore, by acting on that link, the aging process could be slowed most effectively. He considered the circulatory system—the small system connecting other bodily systems—to be the weakest link. As an intervention, he selected blood exchange between two individuals, aiming to achieve conjugation of blood elements. To implement his concept, Bogdanov, as one of the prominent revolutionaries, had sufficient resources to establish the Institute of Blood Transfusion in 1926. However, he soon died while conducting an experiment on himself.

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His student, the renowned Soviet gerontologist and academician A. A. Bogomolets (1881–1946), adopted and somewhat modified his teacher's ideas (Bogomolets, 1940; Duplenko, 1985; Frolkis, 1988). In his view, the leading role in aging belongs not only to blood, but to connective tissue in general. As a method of combating aging, he proposed activating connective-tissue functions by introducing antibodies against it. In this case, as a result of the immune response, degradation of some cells would stimulate the activity of other cells of that tissue. In essence, this mechanism resembles cell therapy, and, similarly, the effectiveness of Bogomolets' method in extending life is far from clear. Today, this approach is largely being supplanted by hormonal therapy and immunostimulation.

Conclusion

Physiology serves as the principal scientific foundation in the formation of gerontology. In-depth study of aging processes in the human organism and age-related changes in its physiological systems forms the theoretical and practical basis of gerontology. Physiological knowledge makes it possible to develop recommendations aimed at slowing aging, preventing disease, and increasing life expectancy. Therefore, both theoretical and applied knowledge in physiology is of critical importance for the advancement of gerontology.

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