

THE DEVELOPMENT OF PHYSIOLOGY, ITS ROLE IN MEDICINE, FUNCTIONAL REGULATION, SYSTEMIC UNITY, AND BIOELECTRICAL PHENOMENA

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Abstract. This article examines the scientific foundations and historical development of physiology, its essential role in modern medicine, and its contribution to understanding functional regulation and systemic integration within the human organism. Through analysis of classical physiological theories and contemporary biomedical research, the study explores neurohumoral regulation, homeostatic mechanisms, and the integrative principles that maintain the organism as a unified biological system. Furthermore, the article investigates the nature of bioelectrical phenomena in excitable tissues, including the mechanisms of resting membrane potential and action potential generation in nerve and muscle cells. Drawing upon contributions from modern physiology, neurobiology, and clinical diagnostics, the study emphasizes physiology's central role in medical science and its importance for understanding disease, developing therapeutic strategies, and advancing biomedical technologies. The findings demonstrate that physiology forms the conceptual core of clinical reasoning and remains indispensable for interpreting normal and pathological states of the human body.¹

Keywords: Physiology; homeostasis; neurohumoral regulation; excitable tissues; bioelectricity; medical science; systemic integration; action potential; membrane physiology; biomedical research; functional regulation.

Introduction. Physiology is one of the most fundamental biomedical sciences, dedicated to understanding the mechanisms that sustain life at molecular, cellular, tissue, organ, and systemic levels. Its conceptual foundations emerged in antiquity, yet the discipline began to take shape as an experimental science in the nineteenth century with the works of Claude Bernard, Hermann Helmholtz, Carl Ludwig, and Ivan Pavlov, whose discoveries on internal environment stability, nerve conduction, and conditioned reflexes laid the groundwork for modern physiology.² Today, physiology is closely integrated with molecular biology, neurobiology, bioengineering, systems science, and clinical medicine, serving as the theoretical basis for diagnosis, therapy, and biomedical innovation.³ The aim of this article is to analyze the development of physiology, reveal its medical significance, and examine how regulatory and bioelectrical mechanisms ensure organismal unity.

Main Body. Physiology plays a foundational role in medicine because every clinical discipline—from cardiology and neurology to endocrinology, gastroenterology, and nephrology—depends on understanding normal physiological processes.⁴ Diagnostic methods such as electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), ultrasonography, laboratory testing, and functional assessments all rely on measuring physiological parameters to detect deviations from normal function.⁵ Modern therapeutic strategies also arise from physiological principles: pharmacology is based on cellular receptor mechanisms; surgery depends on cardiovascular and respiratory physiology; and intensive care relies on understanding homeostatic regulation. Functional regulation within the body is mediated by neurohumoral integration—a coordinated interaction between the nervous and endocrine systems. The nervous system provides rapid, targeted responses via electrical impulses that regulate sensory perception, motor activity, and reflex pathways.⁶ The endocrine system, by contrast, controls long-term processes such as growth, metabolism, reproduction, and stress adaptation through hormones that act on distant tissues.⁷ Neuroendocrine integration ensures complex adaptive responses such as blood pressure stabilization, thermoregulation, glucose balance, fluid and electrolyte homeostasis, and coordinated digestive activity. These processes maintain homeostasis, the dynamic equilibrium described by Claude Bernard and later expanded by Cannon's theory of self-regulation.⁸ Organismal unity is a central principle

of physiology. No organ functions in isolation; instead, all systems are interconnected through neural, hormonal, and circulatory pathways. The cardiovascular system distributes nutrients, gases, hormones, and metabolic products; the respiratory system maintains gas exchange and acid–base balance; the renal system controls osmolarity and excretion; and the immune system provides biological defense.⁹ Systems biology further demonstrates that the nervous, endocrine, and immune systems form an integrated regulatory network, providing evidence that psychological, physiological, and metabolic processes operate within a single functional continuum.¹⁰ Within this unified system, excitable tissues—nerve and muscle—play a crucial role because of their ability to generate and propagate bioelectrical impulses. The resting membrane potential results from differential ion distribution and selective membrane permeability, while the action potential arises through rapid depolarization and repolarization mediated by voltage-gated sodium and potassium channels.¹¹ In neurons, action potentials enable long-distance signal transmission and synaptic communication through neurotransmitters. In muscle fibers, electrical excitation triggers contraction by activating the actin–myosin interaction.

Bioelectrical phenomena also form the basis of clinical diagnostics: abnormalities in nerve conduction, muscle excitability, or cardiac electrical activity indicate neurological disorders, neuromuscular diseases, or cardiac arrhythmias. Thus, physiology—through its study of regulatory mechanisms, systemic integration, and excitable cell behavior—remains essential for understanding health and disease and continues to serve as the intellectual foundation of modern medical practice.

Conclusion. Physiology, as a core biomedical science, provides a comprehensive understanding of the mechanisms that support life and form the basis of clinical medicine. Its historical development, integration with modern biomedical research, and central role in diagnosing and treating disease demonstrate its enduring importance. Neurohumoral regulation, homeostatic mechanisms, organismal unity, and bioelectrical processes in excitable tissues collectively illustrate the complexity and coherence of the human body. Physiology not only explains normal functional processes but also guides clinical decision-making, therapeutic innovation, and scientific inquiry. As biomedical science advances,

physiology continues to serve as the conceptual and methodological foundation for medical progress and the understanding of human health.

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