Oriented towards People's Life and Health: Enhancing the Overall Capacity of National Medical Science and Technology (Postprint)

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Abstract

Medical and life health sciences constitute the most dynamic and strategically promising sector at the global scientific frontier and within national scientific and technological innovation systems, serving as a critical safeguard for improving public health, advancing social civilization, and ensuring national security. China faces challenges of weak foundational medical research, limited frontier breakthroughs, and high external dependence on medical equipment and instruments, making it imperative to strengthen weak areas, address deficiencies, and reinforce the entire system. Guided by the "Four Orientations," China must enhance strategic thinking and adopt a systematic perspective to comprehensively plan medium- and long-term development of medical science and technology, thereby shaping the overall capacity of national medical science and technology. To this end, this paper proposes eight recommendations: optimizing top-level design, improving investment mechanisms, strengthening basic research, promoting interdisciplinary convergence, enhancing technology transfer, fostering open collaboration, reinforcing bottom-line thinking, and emphasizing ethical norms.

Full Text

Improving Overall Capability of Chinese Medical Science and Technology for Targeting People's Health

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Abstract

Medicine and life health constitute the most dynamic and strategically promising sector in the global scientific frontier and national innovation system, serving as a critical guarantee for improving public health, advancing social progress, and safeguarding national security. China's medical research suffers from weak basic research, limited breakthroughs at the frontiers, and high dependence on foreign medical equipment and instruments. Strengthening weak links, addressing shortcomings, and enhancing the entire system have become urgent imperatives. Guided by the "Four-Pronged Strategy," China must strengthen strategic and systematic thinking, comprehensively plan medium- and long-term medical science and technology development, and shape its overall national capacity in medical science and technology. To this end, this paper proposes eight recommendations: optimizing top-level design, improving investment mechanisms, consolidating basic research, promoting interdisciplinary convergence, strengthening achievement transformation, enhancing open collaboration, reinforcing bottom-line thinking, and emphasizing ethical norms.

Keywords: targeting people's health; COVID-19; interdisciplinary integration; science and technology innovation

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In 2020, President Xi Jinping first proposed the "Four-Pronged Strategy" at a symposium with scientists, establishing "targeting people's life and health" as a strategic priority in national modernization and research deployment. The 20th National Congress of the Communist Party of China further reinforced this orientation, placing the protection of people's health in a position of "priority development." Medical science and technology innovation represents the key lever for safeguarding people's life and health and serves as a critical foundation for building "two centers and one highland" (science center, talent center, and innovation highland). The overall capacity of this sector directly determines the progress and prosperity of the life and health domain. Beyond the frequently discussed "bottleneck" core technologies, China's medical science and technology still faces significant developmental constraints, with its overall capabilities falling short of the standards required for high-level self-reliance and the construction of a world science and technology power. Substantial gaps remain in medical devices, new drug research and development, and the modernization of traditional Chinese medicine, creating what can be described as "gaping holes" and "chasms" in these areas.

1. The New Era Calls for High-Quality Development of Medical Science and Technology

1.1 Improving People's Health and Well-Being Increasingly Relies on Medical Science and Technology Innovation "Targeting people's life and health" represents a new demand of the new era—the urgent need to respect and protect people's lives and health—and an inevitable trend for the medical field to gain strategic status as the nation advances toward becoming a world science and technology power. The primary goal of medical science and technology innovation is to better satisfy people's aspirations for healthy and happy lives and to effectively address major medical issues affecting public health and economic-social development. Grasping the people-centered development philosophy, medical science and technology innovation undoubtedly constitutes a matter of national importance and heavy responsibility.

Since the reform and opening up, rapid national economic and social development has gradually raised living standards to a moderately prosperous level, substantially enhancing household economic capacity and dramatically expanding production and lifestyle options. These changes have fundamentally altered the disease spectrum as application scenarios have broadened. The incidence of major chronic non-communicable diseases has risen significantly, including cardiovascular and cerebrovascular diseases, cancer, respiratory and circulatory system diseases, diabetes and other metabolic disorders, and neuropsychiatric conditions, all severely impacting public health. Meanwhile, accelerated population aging has led to rapid growth in age-related and degenerative diseases such as Alzheimer's disease, Parkinson's disease, and bone disorders. Additionally, issues like birth defects, improper medication use, misdiagnosis in traditional Chinese medicine, and injuries from accidents and disasters continue to affect residents' health and happiness, imposing heavy burdens on the national economy and society. Without high-level medical science and technology, comprehensive health support and full modernization cannot be achieved, making the improvement of people's well-being increasingly dependent on rapid medical science and technology innovation.

1.2 Technology Blockade Requires Medical Science and Technology Innovation to Gain Late-Mover Advantage In recent years, Western countries, led by the United States, have intensified containment and even blockades against China's science and technology innovation, particularly in high-end, sophisticated, and scarce technology fields. Like other high-tech sectors, China's medical science and technology faces numerous risks of "bottlenecks" in key core technologies. The risk of supply disruption is particularly acute for high-end scientific research instruments and experimental equipment used in medical research. Large-scale analytical instruments frequently used in grade-two and above hospitals (such as nuclear magnetic resonance spectrometers and high-resolution mass spectrometers) and high-level imaging equipment (such as magnetic resonance imaging devices, super-resolution fluorescence microscopes,

and cryo-transmission electron microscopes) cannot achieve independent and controllable technology and must be obtained through foreign technology introduction and equipment purchases.

Since the China-U.S. trade friction, the United States has strengthened its technological blockade in the medical science and technology field through legislation such as the *U.S. Innovation and Competition Act of 2021*, which invests over $200 billion in frontier technology sectors. These measures aim to suppress China's "secondary innovation" in pharmaceutical science and technology and continuously contain China's growing international influence in the medical and health field. Although China has established various biomedical research centers in recent years, such as the National Center for Protein Science (2010), China National GeneBank (2016), and National Bioinformation Center (2016), these initiatives started late and suffer from insufficient technological accumulation. Meanwhile, the pharmaceutical science and technology field faces numerous problems, including massive misallocation of innovation resources, prevalence of "small, scattered, short, and shallow" research, inadequate application of modern scientific methods to study active ingredients and pharmacological mechanisms of traditional Chinese medicine, and weakness at both ends of the innovation chain—"original innovation" and "transformation and application"—with basic research results represented by papers and patents failing to translate into applied outcomes and "bottleneck" breakthrough capabilities. As pressure mounts for disruption of large-scale medical equipment supplies, China must fundamentally abandon the "follower" research and "me-too" development models and urgently cultivate national strategic medical science and technology forces.

1.3 Recurring COVID-19 Pandemic Demands Enhanced Infectious Disease Prevention and Emergency Medical Research COVID-19 represents one of the most challenging global health issues of the 21st century. Although China has achieved overall success in coordinating epidemic prevention with economic development, its comprehensive capacity for infectious disease prevention and emergency medical research remains concerning. Compared with developed countries, China still lacks sufficient research capabilities and timely responses in major infectious disease pathogenesis, pathology research, virus traceability, and pharmacological research. China needs to strengthen epidemiology and infectious disease research, track and trace major viruses, and sustain investment in innovative drug development to avoid situations where major infectious diseases can only be addressed through formulation modifications or traditional pharmaceutical models. China's medical institutions at various levels demonstrate uneven capacity to respond to emergencies, and medical laboratories and specialized research platforms are insufficient to meet the needs of emergency research breakthroughs, making seamless connection between new drug development and clinical application difficult. Infectious disease prevention and emergency medical science and technology capabilities urgently need improvement, requiring strengthened development of emergency prevention and control systems such as "nucleic acid information early warning systems" and

"medical data visualization" [1] to effectively improve the efficiency of medical prevention and control workers, reduce the risk of missed infectious disease detection, and comprehensively enhance prevention capabilities and emergency public health science and technology levels [2].

2. Strategic-Level Enhancement of Medical Science and Technology Innovation Systematization

2.1 Planning Medical Science and Technology Development Strategy with Systematic Concepts Medical science and technology requires grasping dynamic systematic coordination, achieving overall planning and comprehensive balance, and discerning trends within strategic frontiers. It should adopt complex scientific theoretical thinking and practical strategies represented by systems science to carry out medical and health technology research, development, and process management. Based on this, some scholars argue that China urgently needs to build an integrated composite health service system that integrates front-end research activities and educational activities in the innovation chain, mid-end service and prevention undertakings, and back-end management activities to maximize its capacity to address future challenges [3]. Through systematic macro-level control, medical science and technology innovation can better conform to the laws of science and technology management and the needs of people's life and health, driving overall optimization and advancement of China's medical science and technology through key point breakthroughs.

Systematic concepts in medical science and technology development strategy should be reflected in at least three aspects: First, balancing internal relationships within the medical science and technology system by coordinating research and development in medicine, pharmaceuticals, clinical practice, and public health, adhering to prevention-first combined with treatment, major chronic disease prevention combined with infectious disease control, and physical-mental-spiritual coordination. Second, transcending functional department limitations and project domain constraints to guard against "tunnel vision," achieving holistic allocation of science and technology resources through systematic perspectives, and integrating considerations of medical platform construction, scientific talent introduction, and equipment funding support while applying different support mechanisms to scientific, technological, and engineering problems. Third, managing relationships among various task sectors related to medical science and technology, connecting medical science and technology innovation with medical talent development, medical science and technology management, traditional Chinese medicine modernization, and medical platform construction, while coordinating the consistent advancement of medical science and technology innovation with medical facilities and health governance innovation.

2.2 Formulating Long-Term Medical Science and Technology Plans with Strategic Vision Formulating and implementing development plans for major undertakings represents an important manifestation of China's institu-

tional advantage in concentrating resources to accomplish major tasks. National-level medical science and technology planning must be based on medium- and long-term visions, oriented toward the goal of becoming a world science and technology power, emphasize strategic vision, and properly address major issues related to medical science and technology itself and its associated ethical governance, risk prevention, science popularization, institutional innovation, and scientific community building to provide a favorable macro-environment for medical science and technology development.

Strategic thinking in medical science and technology encompasses essential thinking and cross-boundary thinking. This requires examining domestic and international development environments from the perspective of "two overall situations," gaining insights into medical science and technology trends and patterns, transcending disciplinary and domain boundaries as well as industry-academia-research organizational boundaries, and strengthening the critical supporting role of medical science and technology in enhancing innovation system effectiveness, national comprehensive strength, and people's well-being. Currently, life and health has become the sector with the greatest growth potential and spillover effects in the science and technology innovation system. The country that first achieves disruptive breakthroughs in this domain will secure an invincible position in international competition. The life and health field itself possesses characteristics of a complex giant system. In strategic planning, beyond comprehensively balancing medical and pharmaceutical science and technology, it is also necessary to manage relationships between medical science and technology elements and related fields. Breakthroughs in derivative fields such as precision medicine and synthetic biology not only enhance people's health and well-being but also possess tremendous industrial and national security value. Meanwhile, China must maintain "openness" and "compatibility," drawing upon cutting-edge medical science and technology essence from worldwide frontiers and basic research, strengthening the excavation of traditional Chinese medicine advantages, and using modern scientific techniques such as genomics, proteomics, and bioinformatics to promote in-depth collaboration with countries worldwide, thereby providing scientific foundations for traditional Chinese medicine modernization. Furthermore, from the perspective of medical development trends, China must strengthen clinical and translational research originating from clinical scientific questions, value the organic combination and deep integration of basic medicine with clinical medicine, and promote both vertical disciplinary deepening and horizontal interdisciplinary convergence.

2.3 Promoting Evolutionary Development of Medical Science and Technology Innovation System with Innovative Thinking In practice, the science and technology innovation system and mechanism remain a shortcoming in China's modernization of governance systems and capabilities. The theoretical framework for the medical science and technology innovation system has not been fully constructed, with related discussions being relatively scarce,

which will constrain the sustainable and high-quality development of science and technology innovation. For instance, science and technology innovation investment has not yet become a binding indicator for governments at all levels, research ethics norms remain weak in many cases, and industry-academia-research collaboration lacks effective incentive mechanisms. Science and technology innovation and institutional innovation are like the two wings of a bird or the two wheels of a cart. Institutional arrangements for medical science and technology should be a process that keeps pace with the times and dares to innovate, reshaping theoretical exploration, methodological application, path setting, and task selection through institutional and mechanism innovation. Medical science and technology institutional and system innovation constitutes an important guarantee for promoting the development of the medical science and technology innovation system from the perspective of institutional regulations and policy practices.

As a "life-and-death" undertaking, medical science and technology innovation requires more urgent institutional guarantees. Potentially breakthrough medical frontier directions develop responsively with the emergence of major diseases and the expansion of major basic frontiers, necessitating further exploration of adaptive and flexible medical science and technology funding and governance mechanisms. Based on innovation organization and strategic management theories, the reconstruction of China's medical science and technology innovation system urgently needs to connect the entire chain from basic life and health research to pharmaceutical synthesis technology breakthroughs, diagnostic and predictive technology applications, and new drug development and industrialization [4]. The construction of the medical science and technology innovation system should dynamically form institutional frameworks, improve basic institutions, and stimulate the activity of medical innovation entities and elements during development, gradually evolving into a medical innovation system with complete entities, clear positioning, and superior functions.

3. Strategies for Strengthening Medical Science and Technology Innovation Focused on Medium- and Long-Term Goals

3.1 Optimizing Top-Level Design to Consolidate Legal Guarantees for Medical Science and Technology Development Legally safeguarding and promoting high-quality, sustainable medical science and technology innovation represents an important choice for modern governance. Through standalone or integrated legal system construction, China should clarify funding entities, investment mechanisms, regulatory responsibilities, emergency responses, and collaborative relationships among pharmaceutical exploration, health and sanitation, disease control, medical institutions, and research and development organizations. Under improved legal guarantees, top-level design for medical science and technology development should focus on setting research and development domain layouts, emergency research and development responsibilities, innovation platforms, talent cultivation, and technological reserves. The strate-

gic planning objectives proposed in the *Healthy China 2030 Planning Outline* urgently require building a medical science and technology innovation system to organize and implement major medical science and technology projects and breakthroughs through collaborative innovation.

3.2 Improving Investment Mechanisms to Stimulate Medical Science and Technology Innovation Vitality Science and technology innovation competition constitutes the core of current great power competition, with medicine and life and health serving as the main battleground. The medical field features strong clinical operation characteristics and high interdisciplinary integration, requiring diversified and classified talent and funding investment mechanisms and personalized management approaches according to its characteristics and in accordance with the laws of medical academic development, medical talent growth, and medical management. To address the overall shortcomings in medicine, China can draw lessons from the mechanism design of the U.S. National Institutes of Health (NIH) and establish a unified national-level biomedical funding system encompassing existing funding entities such as the Medical Science Department of the National Natural Science Foundation of China and the Chinese Academy of Medical Sciences [5]. This would enable national-level coordination of scientific research resource allocation, strengthen talent cultivation and team building in cutting-edge medical research fields such as translational medicine, and create national strategic science and technology forces in the medical field. Simultaneously, it should provide global molecular information databases and other basic data facility support, collecting and integrating basic data, diagnostic information, disease phenotypes, genomics, proteomics, and other omics information to enhance infrastructure construction in the pharmaceutical system and endow traditional Chinese medicine's unique diagnostic and treatment methods with scientific connotations. Notably, support for medical science and technology innovation cannot rely solely on government, especially central government, investment but should fully stimulate the enthusiasm of diverse entities including research institutes and pharmaceutical leading enterprises, and even broadly leverage social resources.

3.3 Consolidating Basic Research to Enhance Original Medical Contributions Basic research constitutes an important source of high-tech industries, an irrefutable consensus in the science and technology academic community. Since the 20th century, breakthrough innovations have often originated from major scientific theoretical propositions, with the birth of emerging industries becoming inseparable from basic research in frontier technology fields. For example, the discovery of the DNA double helix structure laid the foundation for modern medical genetics and biotechnology engineering. Looking forward, China still needs to strengthen support for globally hot innovation fields such as genomics, proteomics, and metabolomics to catalyze comprehensive improvement in medical science and technology innovation levels. Additionally, China must promote research breakthroughs in clinical medicine target technologies,

disease mechanism exploration, traditional Chinese medicine pharmacological mechanisms, new drug research and development and application, and experimental animal cultivation [6]. Furthermore, relying on basic research of human health issues, China should integrate existing preventive biology, clinical diagnostics, basic pathology, pharmaceutical development and interdisciplinary research, and medical artificial intelligence research to consolidate the entire innovation chain from basic research to clinical diagnosis and treatment.

3.5 Strengthening Achievement Transformation to Comprehensively Support Clinical Diagnosis and Treatment Level Improvement The ultimate purpose of medical science and technology development is to protect people's life and health and enhance human well-being, which depends on transforming innovative achievements into clinical technologies and solutions. Basic medicine and clinical medicine constitute the two wings of medical science and technology, whose organic combination can illuminate, nourish, and achieve mutual success. Basic medicine focuses more on theoretical frontiers, while clinical medicine emphasizes practical application. Balancing both facilitates targeted and effective high-quality innovation research. If both are committed to addressing scientific and technological issues in life and health, the most valuable research should originate from clinical practice (the source of scientific and technological questions), surpass clinical practice (using internationally accepted scientific methods to refine and summarize problems), and return to clinical practice (final research results can be transformed into clinical applications). As is well known, research that proceeds purely from literature to literature only identifies research entry points and focus from literature gaps, lacking awareness of finding and studying real problems from clinical practice, which offers no benefit for solving practical people's life and health issues. Today's leading innovative countries worldwide have strengthened cooperation between basic medical research and clinical research to accelerate the translation of research results into clinical applications. China's medical science and technology innovation urgently needs to balance basic and clinical medicine, strengthen clinical and translational research originating from clinical scientific questions, and use translational medicine as a bridge to promote the transformation and application of cutting-edge medical knowledge.

3.6 Enhancing Open Collaboration to Expand International Cooperation in the Medical Science and Technology Community Medicine is one of the most important science and technology fields that can easily gather maximum consensus from the high ground of human morality and best promote people-to-people bonds. Under the call of a community with a shared future for mankind, strengthening international pharmaceutical cooperation and jointly addressing global life and health risks and challenges such as major infectious diseases represents the common mission of medical science and technology communities in China and worldwide. From the perspective of openness in science and technology undertakings and groups, medical science and technology inno-

vation should actively accept external oversight from the science and technology community and society, while strengthening the role of science and technology societies and other organizations in reinforcing scientific ethics self-discipline and cultivating excellent academic styles. China should promote standardization and normalization represented by traditional Chinese medicine to increase credibility and feasibility in medical science and technology. Additionally, China should further enhance the sense of mission and global responsibility of its medical science and technology community, promote the construction of an open, trusting, and cooperative global health community, and use medical science and technology as an important strategic support for building a community with a shared future for mankind, demonstrating new roles and responsibilities for China's medical science and technology community in global science and technology governance.

3.7 Strengthening Bottom-Line Thinking to Coordinate Medical Innovation Development and Biosecurity Biosecurity constitutes a strategic component of the world's medical undertakings^{1}. In recent years, frequent bioterrorism incidents and food and drug safety events worldwide have made security assurance a new connotation of public health. Strengthening medical science and technology support to protect people's life and health, prevent and respond to biosecurity risks, and control major emerging infectious diseases represents important content for safeguarding national security. Coordinating medical science and technology development and security requires, on the one hand, promoting the secure development of medical science and technology itself, including advancing discipline construction in the medical field, safeguarding medical talent security, and ensuring medical information security and disease resource security. On the other hand, it requires using medical science and technology innovation to guarantee and safeguard national security, improving medical science and technology research and development mechanisms, strengthening investment and supervision of various medical laboratories, and orderly conducting research in fields such as biological breeding under the premise of ensuring biosecurity. Furthermore, China's population and health sector faces challenges from industrialization, urbanization, aging, modern lifestyles, unsafe living environments, natural disasters, and globalization. From the perspective of medical science and technology innovation, China must fully reveal the impact mechanisms and deep-level patterns of these factors on health, providing scientific foundations for addressing these challenges, which also constitutes a substantive contribution of medical science and technology to maintaining overall national security.

3.8 Emphasizing Ethical Norms to Foster a Concept of Medical Science and Technology for Good and Social Responsibility Current human society depends on new and powerful science and technology more than any previous era, yet also worries more than ever about scientific trust crises caused by artificial intelligence, genetic modification, and other technologies,

and is troubled by collective human anxiety triggered by science and other global common issues. Medical science and technology development should grasp the "double-edged sword" characteristic of technology itself, think proactively about ethical challenges brought by cutting-edge medical technology development, and strengthen risk prevention and control at the source. Medical ethics is the field of science and technology ethics most closely related to and profoundly affecting humanity. Research ethics risk prevention and technology-for-good mechanisms are far more important in medical science and technology innovation than in other fields. For example, incidents such as "gene-edited babies" and "experimental animals for traditional Chinese medicine" have exposed the absence of ethical governance in China. Therefore, China must attach importance to ethical risk prevention in cutting-edge medical science and technology, improve ethical review mechanisms for medical science research, and balance the relationship between medical science and technology development and ethical governance. It should both promote rapid development at the frontiers of medical science and technology and strengthen ethical governance in new technology applications. Strengthening health education and health knowledge popularization constitutes important content for medical science and technology development. Universal medical health education forms the cultural foundation and heritage of a nation and determines its future science and technology governance and social development. Meanwhile, medical science popularization helps establish public trust in medicine and helps nurture fertile soil for medical science and technology innovation development.

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Note: Figure translations are in progress. See original paper for figures.