Strengthening Basic Research to Consolidate the Foundation for Scientific and Technological Self-Reliance and Self-Strengthening: Postprint

Authors: Zhang Xianen, Weihua Wang, Yan Xiyun, Jiaofeng Pan

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Abstract

Strengthening basic research constitutes an urgent imperative for achieving high-level scientific and technological self-reliance and represents the essential pathway to establishing a world-leading science and technology powerhouse. This article proceeds from the perspective of basic research and high-level scientific and technological self-reliance to synthesize reflections by frontline scientists and administrators on the significance of strategic basic research and organized basic research in confronting major fundamental social development challenges and achieving breakthroughs in key core technologies. It posits that basic research necessitates an inclusive ecosystem, that without basic research there exists no intellectual fountainhead for invention and innovation, and moreover, that some of the most promising research origins in basic research should emerge from applications and even practical production and daily life. Strategic basic research, operating within the broader framework of basic research, emphasizes major scientific questions distilled from economic and social development issues and exerts direct influence on resolving real-world problems. Organized basic research entails the systematic pursuit of relatively well-defined objectives with adequate resource guarantees and support, enabling the nation to sustain development and leadership in cutting-edge scientific and technological domains. Constructing a basic research-rooted innovation-driven development paradigm requires the concerted efforts of multiple stakeholders, encompassing guiding enterprises to enhance basic research investment, promoting collaborative basic research between enterprises and universities and research institutes, and strengthening government policy formulation and implementation, thereby establishing an efficient innovation system founded upon basic research.

Full Text

Strengthening Basic Research and Consolidating the Foundation for Sci-Tech Self-Reliance and Self-Improvement

Authors: Zhang Xian'en, Wang Weihua, Yan Xiyun, et al.

Affiliations: - College of Synthetic Biology, Shenzhen Institute of Advanced Technology (Preparatory) - Institute of Biophysics, Chinese Academy of Sciences - Songshan Lake Materials Laboratory - Institute of Physics, Chinese Academy of Sciences - Institutes of Science and Development, Chinese Academy of Sciences

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Strengthening basic research is an urgent requirement for achieving high-level scientific and technological self-reliance and a necessary path toward building a world leader in science and technology. This article examines the relationship between basic research and high-level sci-tech self-reliance, synthesizing perspectives from frontline scientists and managers on the importance of strategic basic research and organized basic research in addressing major socio-economic development challenges and achieving breakthroughs in key core technologies. We propose that basic research requires an inclusive ecosystem: without basic research, there would be no intellectual source for invention and creation, yet simultaneously, valuable research origins in basic science should emerge from applications and even practical production and daily life. Strategic basic research operates within the framework of basic research, focusing on major scientific questions distilled from socio-economic development problems while having direct relevance to solving practical challenges. Organized basic research involves conducting research around relatively clear objectives with corresponding resource guarantees and support, enabling the nation to maintain development and leadership in cutting-edge scientific and technological fields. Building an innovation-driven system rooted in basic research requires multiple stakeholders to play joint roles in guiding enterprises to increase basic research investment, promoting collaboration between enterprises and universities/research institutes on basic research, and strengthening government policy formulation and implementation, thereby establishing an efficient innovation system with basic research as its foundation.

Keywords: Basic research, Strategic basic research, Organized, Innovation-driven

Basic Research and High-Level Sci-Tech Self-Reliance

High-level sci-tech self-reliance and self-improvement is simultaneously a goal, a strategy, and a system. Within this entire system, basic research undoubtedly constitutes the foundation, which fully demonstrates its extreme importance. On the afternoon of February 21, 2023, the Political Bureau of the CPC Central Committee held its third collective study session on strengthening basic research.

General Secretary Xi Jinping emphasized that strengthening basic research is an urgent requirement for achieving high-level sci-tech self-reliance and a necessary path toward building a world leader in science and technology. In recent years, the share of basic research in national investment has steadily increased. In 2022, basic research accounted for 6.32% of R&D investment, reaching nearly 200 billion yuan—a proportion that will certainly rise further.

Therefore, we must both emphasize consolidating the foundation of basic research and focus on leveraging its role as a source of vitality. Basic research has two driving forces: first, the internal contradictions and laws of the knowledge system, which primarily reflect scientists' curiosity and free exploration; second, strong external demand-driven forces, which are more goal-oriented and application-driven. Basic research requires an inclusive ecosystem for scientific and technological innovation. When a serendipitous discovery can gain acceptance from scientists across different fields, receive support from strategic scientists for interdisciplinary initiatives, and obtain small-scale funding, it can be pursued and even flourish. For instance, nanozymes represent a new concept proposed by Chinese scientists and represent an original frontier scientific discovery led by China that has attracted widespread attention both domestically and internationally. The incubation of this original scientific achievement is closely related to the nation's innovation ecosystem in recent years. Around 2000, there was particular emphasis on interdisciplinary integration, bringing together physics, life sciences, and chemistry for discussion. It was within this favorable innovation ecosystem that nanomaterials met enzymes, leading to the discovery that nanomaterials possess catalytic functions similar to enzymes. Thus, beyond the research itself, the ecosystem in which innovation occurs is equally crucial.

Basic research is the source of invention and creation, while production and application also pose practical questions to basic research. On one hand, basic research reveals possibilities; without its achievements, there would be no intellectual source for invention. For example, Maxwell's electromagnetic field theory, developed through basic research, enabled German scientist Hertz to experimentally discover electromagnetic waves years later, which were then applied to communications and other fields, fundamentally transforming society. Without Maxwell's theoretical precedent, others would not have discovered electromagnetic waves. On the other hand, basic research is closely connected to production and application, with applied basic research topics often originating from practical production and even daily life. For example, the reason Songshan Lake Materials Laboratory could be rapidly established within just five years and has already produced many effective outcomes is precisely because its builders could leverage the long-term accumulation of basic research exploration from the Institute of Physics, Chinese Academy of Sciences, enabling relatively quick utilization of Dongguan's favorable industrial environment through certain mechanisms, coupled with strong local government support that facilitated rapid translation of research results.

Basic Research and Strategic Basic Research

China's basic research over the more than 40 years since reform and opening up has experienced three stages: limited support, stable support, and now strengthened support. Throughout this process, interaction with the international community has led to the development of the concept of strategic basic research. Strategic basic research primarily refers to basic research with clear objectives, significant importance, and long cycles, featuring organizational models and resource allocation patterns distinct from dispersed free exploration. It is goal-oriented and driven by application-led demand, representing a category of organized basic research with strong institutional characteristics. The former National "973" Program was a typical example of strategic basic research, addressing not only major issues in socio-economic development but also catalyzing numerous significant fields such as nanotechnology, quantum science, protein science, and stem cells.

Strategic basic research is mainly categorized by two types of drivers:

1. **Scientific goal-driven research.** The Large Hadron Collider cost billions of dollars with the explicit goal of finding the Higgs particle. The Human Genome Project transformed life science research paradigms upon completion, moving life sciences from reductionism to systems theory or a combination of both, elevating our understanding of life laws and disease mechanisms to a new level. Simultaneously, it generated a series of technological extensions, such as the rise and development of synthetic biology, which has had major impacts on biotechnology and industrial development and contributions to human health.

2. **Application purpose-driven research.** Nuclear fusion represents a potential ultimate energy source, and the construction of the International Thermonuclear Experimental Reactor (ITER) aims to verify this goal scientifically and experimentally. The progression from conventional computers to supercomputers to quantum computers all involves clear research objectives. A ultimate goal of synthetic biology is to synthesize cells. Cells are composed of numerous biological macromolecules such as proteins and nucleic acids. While the structure and function of individual proteins are understood through research, new functions emerge when multiple proteins form complex structures. Numerous complexes constitute subcellular structures, cells (with metabolic life characteristics), tissues, organs, and even advanced life individuals. Each biological level exhibits new biological functions, yet the underlying principles remain unclear. Stepwise synthesis of biological structures represents a new paradigm in life science research, and its spillover effects will be substantial.

The Significance of Organized Basic Research for Breakthroughs in Key Core Technologies

Multiple paradigms and forms of basic research can coexist, with appropriate approaches adopted for different disciplines and fields. A current trend in basic research is increasing organization—manifested in topic selection, research processes, resource allocation, and policy support—with different forms of organization at various stages to improve R&D efficiency. Major scientific questions are complex and massive systematic problems that are difficult to complete through individual efforts. Therefore, proposing organization in basic research is necessary. Meanwhile, in the process of organized, large-scale, institutionalized research on major scientific questions, many other unexpected and disruptive discoveries naturally emerge.

Organized basic research is primarily positioned around research content with clear scientific and application goals and major problem-solving directions. For example, climate change has been discussed as an important task by all countries. Global monitoring of greenhouse gases and research on climate change patterns require cross-institutional and even cross-national collaboration, necessitating organizational guarantees. Such research belongs to typical strategic basic research.

Organized basic research can have institutional characteristics. For instance, the development of some fields is particularly suitable for specific research institutions, allowing the consolidation of several important directions around which the entire research institution's personnel can organize and implement research. Songshan Lake Materials Laboratory is a typical new R&D institution of this type, highly suitable for implementing organized basic research.

Organized basic research must guarantee resource allocation. Positioned primarily in research directions with clear scientific and application goals, corresponding resource allocation is crucial. If relevant resources cannot keep pace and researchers must still "involute" to apply for competitive funding, the advantages of organization cannot be realized. For example, in 1945, American scientist Vannevar Bush published the report *Science—The Endless Frontier*, which proposed changes to the model and paradigm of basic research. This facilitated the establishment of foundations in the United States to support basic research related to major scientific problems through government funding and the creation of budget-based research institutions to ensure resource allocation, enabling the United States to maintain long-term leadership in cutting-edge scientific and technological fields.

Building an Innovation-Driven System Rooted in Basic Research

A full-factor, full-chain innovation system is rooted in basic research. Innovation systems can be described across different dimensions, broadly divided into

"hard" and "soft" aspects. The "hard" aspects include infrastructure construction, which is now generally well-addressed. The "soft" aspects include resource allocation models, as well as management and evaluation methods, for which the state now attaches great importance and has adopted many targeted measures to address emerging and legacy issues in development.

Currently, China's basic research funding is almost entirely provided by government support, which differs from the situation in developed countries. Through normalized analysis, we have established a global enterprise innovation landscape for major economies: in terms of enterprise innovation vitality, social innovation capacity, and top 500 patent applications, China is at a comparable level with the OECD average, though with some gap from the United States. However, when comparing investment in basic research, Chinese enterprises lag significantly behind. Today, a considerable number of Chinese enterprises have reached the forefront of their industries. For industries to continue growing bigger and stronger, they must possess a globalized vision, and basic research must keep pace. Research data show that foreign enterprises demonstrate good performance in both the intensity of basic research investment and scientific paper publication, demonstrating the importance of basic research and original innovation for industrial development. As frontline entities in production and application, enterprises are both problem proposers and final transformers of basic research results. Enterprise investment in basic research is significant for enhancing industry (global) competitiveness, addressing insufficient funding for basic research across society, and promoting industry-academia-research collaboration and problem-oriented research. This is an indispensable link for China's science and technology to truly achieve self-reliance and self-improvement.

Songshan Lake Materials Laboratory represents an excellent innovation model. Basic research should encourage broader participation from multiple stakeholders including research institutes, universities, and enterprises. In basic research, Songshan Lake Materials Laboratory serves as a platform where the government has invested in excellent hardware, a group of outstanding scientific talents, and an engineering team. While adhering to openness, collaborating with enterprises to access much innovation and vitality within industry, and bringing together people from different fields—scientists, engineers, and entrepreneurs—for intellectual collision, it represents a very good innovation model based on basic research.

Constructing an innovation system requires multiple stakeholders to play joint roles: government in policy formulation, enterprises in application traction and increased investment, and market in goal orientation, thereby establishing an efficient innovation system rooted in basic research.

Author Biographies

Zhang Xian'en is Dean of the College of Synthetic Biology at Shenzhen Institute of Advanced Technology (Preparatory), Chinese Academy of Sciences, and

a researcher at the Institute of Biophysics, Chinese Academy of Sciences. He is also an editorial board member of *Bulletin of Chinese Academy of Sciences*. His research focuses on synthetic biology, biosensing, nanobiology, and analytical microbiology. E-mail: zhangxe@ibp.ac.cn

Wang Weihua is an Academician of the Chinese Academy of Sciences, Director of Songshan Lake Materials Laboratory, a researcher at the Institute of Physics, Chinese Academy of Sciences, and Director of the CAS Key Laboratory of Extreme Conditions Physics. He is also an editorial board member of *Bulletin of Chinese Academy of Sciences*. His research focuses on amorphous alloy materials and amorphous physics. E-mail: whw@iphy.ca.cn

Yan Xiyun is an Academician of the Chinese Academy of Sciences and a researcher at the Institute of Biophysics, Chinese Academy of Sciences. She is also an editorial board member of *Bulletin of Chinese Academy of Sciences*. Her research focuses on tumor immunology and nanozymes. E-mail: yanxy@ibp.ac.cn

Pan Jiaofeng is President and researcher at the Institutes of Science and Development, Chinese Academy of Sciences, Dean of the School of Public Policy and Management at the University of Chinese Academy of Sciences, and Chairman of the China Strategy Research Society. He is also an editorial board member of *Bulletin of Chinese Academy of Sciences*. His research focuses on science and technology strategic planning, innovation policy, and think tank theory and methods. E-mail: jfpan@casisd.cn

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