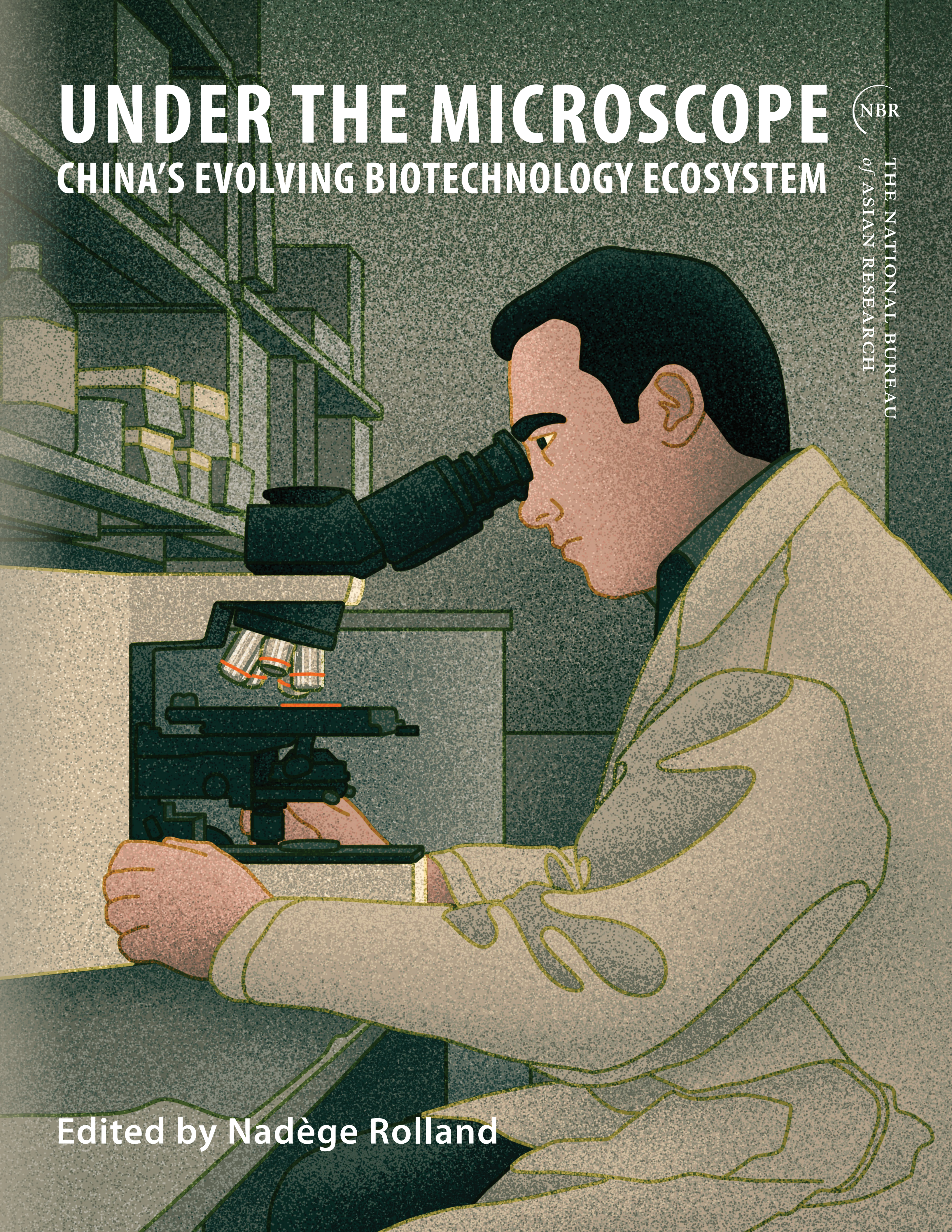
UNDER THE MICROSCOPE

CHINA'S EVOLVING BIOTECHNOLOGY ECOSYSTEM



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China's Evolving Biotechnology Ecosystem

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For further information about NBR, contact:

The National Bureau of Asian Research
One Union Square
600 University Street, Suite 1012
Seattle, Washington 98101

206-632-7370 Phone
nbr@nbr.org E-mail
http://www.nbr.org

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TABLE OF CONTENTS

v Foreword
Nadège Rolland

1 China's Biotechnology Goals: Implications for U.S. Competitiveness
Anna Puglisi

11 The Importance of Genomic Data for China's Global Health Ambitions
Caroline Schuerger and Anna Puglisi

25 The Divergence in Non-human Primate Research between the United States and China: Causes and Implications
Rowan Pierson

41 Chinese Military Thinking at the Crossroads of Biological Security, Biotechnology, and Global Health
Alexis Dale-Huang and Nathan Beauchamp-Mustafaga

FOREWORD

As part of its broader research program dedicated to China's global vision and strategy in the Xi Jinping era, the National Bureau of Asian Research (NBR) identified public health as a key domain in which Beijing is attempting to strengthen its position as a world-class leader. In addition to political and diplomatic activities deployed internationally since 2015 under the Health Silk Road banner,[1] the Chinese leadership has been actively encouraging the development of domestic scientific research and commercial activities in the medical, genomics, neuroscience, and public health domains.

The essays presented in this report examine Beijing's activities in areas crucial to the future direction of biotech research and discovery and provide insights about the potential future biotech landscape in the context of a deepening geostrategic rivalry between China and the United States. Collectively, they point to the emergence of a comprehensive Chinese techno-industrial biotech ecosystem based on the premise of national security and strategic aims. Ethical asymmetries and strict limitations on what Beijing considers as strategic (and therefore non-sharable) resources could create a set of advantages for China's pursuit of scientific leadership. The implications of these apparent trends could be profound for areas as diverse as healthcare, climate change mitigation, agriculture, food security, pharmaceutical development, biodefense, neuroscience, brain modeling, and advanced artificial intelligence (AI).

Anna Puglisi describes biotechnology as a new front of the U.S.-China rivalry. The Chinese leadership has identified the sector as a strategic industry and has been increasingly incorporating military and civilian actors, as well as academic and commercial actors, in order to fulfill its plan to transform China into a biotech superpower. Beijing is moving toward building an increasingly integrated interdisciplinary biotech ecosystem. Its determination raises long-range implications for a wide array of sectors, including agronomics, genomics discovery, and precision medicine, as well as for the future rules of the road that will guide the use of emerging biotechnologies.

Caroline Schuerger and Anna Puglisi examine how China has made genomics a national priority and treats its genomic data as a strategic resource by prohibiting external access to its own genomic data. Genetic data processing, facilitated by the rapid development of AI, supports a sprawling Chinese R&D ecosystem fueling the development of wide-ranging applications, including for public health and biodefense, medicine, agriculture, and food security. The Chinese central leadership's plans for generation, accumulation, and utilization of genetic data are steadily translating into concrete advances, reducing the gap with the United States both in applying current genomic technologies and in developing new capabilities.

Rowan Pierson highlights China's prioritization of non-human primates (NHPs) as a strategic supply. Beijing is investing substantial resources in expanding its NHP research capacity, which plays a crucial role in producing treatments for human diseases and disorders, generating deeper understanding of the human brain, and shaping the future of emerging technologies such as gene-editing tools and AI. Whereas NHP research in the United States has been stagnant for nearly two decades, with public appeals to end primate research entirely, NHP research in China develops in a friendly and supportive environment. Pierson identifies three main areas of divergence in NHP

[1] For further context, see "The Health Silk Road: A Branch of China's Belt and Road Initiative," National Bureau of Asian Research, NBR Special Report, no. 113, December 2024.

research between China and the United States: in attitudes, numbers, and regulations. He cautions that China's approach may facilitate technology transfers and create chokepoints for future U.S. pharmaceutical development, among other critical activities.

Alexis Dale-Huang and Nathan Beauchamp-Mustafaga examine the growing interest of the People Liberation Army (PLA) in the impact that biological issues could have on China's national security objectives, military capability, and future wars. The PLA contributes to China's efforts to position itself as a notable global health player and increase its influence in international global health initiatives. Noting the currently limited understanding of Chinese military thinking on biological security and the military applications of biotechnology, the authors underscore the importance of further research on this topic, including in collaboration with U.S. allies.

NBR would like to extend its special thanks to Rachel Bernstein for her instrumental role in managing the project, as well as Eunwoo Joo, Kanghee Park, Eliot Roberts, and Daniel Schoolenberg for the invaluable research assistance they provided throughout the project's cycle.

Nadège Rolland
Distinguished Fellow, China Studies, NBR

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China's Biotechnology Goals: Implications for U.S. Competitiveness

Anna Puglisi

ANNA PUGLISI is a Visiting Fellow at Stanford University's Hoover Institution. She can be reached at <annabp@stanford.edu>.

EXECUTIVE SUMMARY

This essay highlights China's strategic goals and long-term investments, addresses how these support the foundational work and infrastructure that will drive future discoveries, and examines research in multiple areas that have made tremendous gains—including genomics, bioinformatics, and brain research.

MAIN ARGUMENT

Academia, research, and commerce are becoming the new "geopolitical battlespace" in the U.S.-China technology rivalry, and fields such as biotechnology are the new front in this competition. It will be essential for the U.S., its allies, and other like-minded countries to design a strategy that reflects the values of open democratic societies.

POLICY IMPLICATIONS

- The U.S. needs to invest strategically in the bioeconomy. The early stages of development will be most important for government support and policies. These "first mover" advantages are critical to making new discoveries, and the failure to support nascent industries may produce "chokepoint" ingredients or data for technology development that fast followers cannot recover from.
- The U.S. and like-minded countries need to drive policies that govern the use and storage of genomic data, genomic editing, and animal models that reflect the values of open democratic societies. These policies should include a re-examining of the "biological rules of the road" that includes the sharing of clinical and environmental samples, genomic data, and testing results.
- The U.S. government needs to work with academia, the private sector, and other nations to protect investments in this key sector from theft and exploitation by foreign actors. China's policies and programs undermine the global norms of science.

Emerging technologies are increasingly at the center of global competition, providing the foundational research and development that underpins future industries and drives economic growth. Developments in the biosciences will have far-reaching societal and security implications and create new capabilities for medicine, agriculture, energy, materials, and the environment. While these technologies present extraordinary opportunities, they also have the potential to introduce new threats, such as synthetic pathogens, catastrophic laboratory accidents, and ethical dilemmas surrounding human enhancement, the use of non-human primates, and the modification of human embryos.

The People's Republic of China (PRC) states that it wants to achieve a transformation of China from a "biotech power"(*shengwujishu daguo*) to a "biotech superpower" (*shengwujishu qiangguo*).[1] Drawing on lessons learned from its 5G experience, China has named biotechnology a strategic emerging industry. Its leading biotech companies are acquiring massive amounts of genomic and health data to develop predictive algorithms that provide insights into individuals' disease susceptibilities and facilitate drug discovery. This work will have a direct impact on the global bioeconomy, entrusting the development and control of certain technologies to an authoritarian country with a questionable human rights record. Many assume that whoever finds a cure for certain diseases will automatically share those cures with the world. Given China's human rights record and proclivity to use a heavy hand politically, we make this assumption at our own peril.

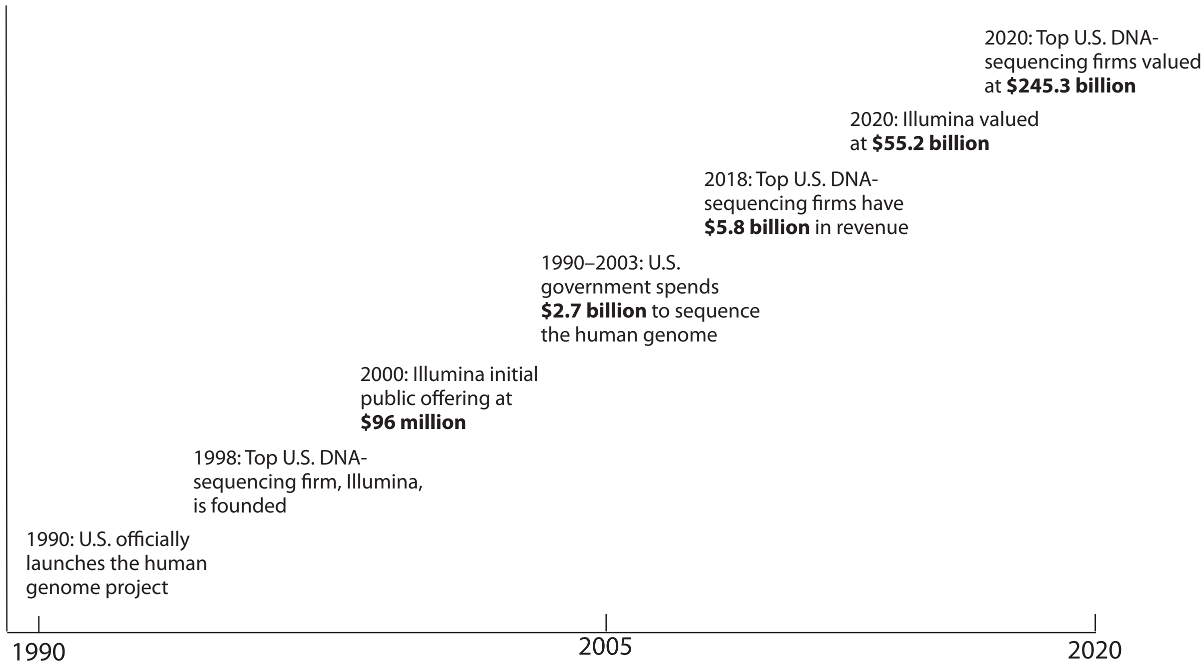
This essay highlights China's strategic goals and long-term investments, addresses how it supports the foundational work and infrastructure that will drive future discovery, and examines research in multiple areas that have made tremendous gains—including genomics, bioinformatics, and brain research. The essay concludes by discussing aspects of China's approach to biotechnology R&D that may lead to either an advantage or a challenge for the United States and like-minded countries, given the applications of this field.

What Is at Stake

The early stages of biotechnology development will be the most critical for developing smart policies that shape the future of the field and protect our investments. By considering the national security implications of biotechnology, the United States and like-minded countries must recognize that not all governments will approach the science with the same drivers or intentions as they do. We cannot assume that others share our values, concerns, or approaches to issues related to lab safety, human subjects, transparency, and reciprocity. Biotechnology leadership that adheres to existing norms will depend on supporting "strategic resources," which include specially designed high-performance computing, genomic data, and access to animal models (especially non-human primates), so that the United States, its allies, and like-minded countries can harness the opportunities that these technologies will bring to humanity and prepare for the challenges that they may present. Much is at stake—both economically and strategically. **Figure 1** depicts the growth of the U.S. DNA-sequencing sector over the last 30 years and highlights the growth of this industry.

1 "Translation: State Council Notice on the Publication of the National 13th Five-Year Plan for S&T Innovation," Center for Security and Emerging Technology (CSET), Georgetown University, January 8, 2020, https://cset.georgetown.edu/publication/state-council-notice-on-the-publication-of-the-national-13th-five-year-plan-for-st-innovation.

FIGURE 1 Growth of the U.S. DNA-sequencing sector



China's Strategic Goals

Over the last two decades, China has put in place policies to support biotechnology and the Chinese bioeconomy, which are intended to foster "big science" facilities, national biomedical "champions" (i.e., favored state and private companies), talent recruitment, and basic research. China views biotechnology as the next industrial revolution and as key to future economic development and comprehensive national power. This state support goes far beyond the traditional industrial policies implemented in Europe and other parts of Asia. It is comprehensive and represents an alternative blueprint for the development of emerging technologies and industries. China's all-embracing approach plays an important role in fostering technology areas that rely on longer timelines, multidisciplinary coalitions, or big science facilities—such as advanced computing, high-end gene sequencing, and colonies of non-human primates. These policies and programs include the following.

China's National Medium- and Long-Term Plan for Science and Technology Development (2006–2020).[2] This S&T blueprint lays out a development strategy that relies on overseas returnees,[3] foreign collaboration, and the R&D laboratories that international companies have established in China to acquire needed skills. The National Medium- and Long-Term Plan focuses both on the process of science and the specific topic areas it seeks to develop.[4] The plan regards the development of Chinese biotechnology as "the new revolution of the 21st century" and emphasizes

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[2] State Council of the People's Republic of China (PRC), "Guojia zhong chang qi kexue he jishu fazhan guihua gangyao (2006–2020 nian)" [National Medium- and Long-Term Plan for Science and Technology Development (2006–2020)], 2006.

[3] "New Policies to Be Issued to Lure Overseas Students Home," *People's Daily*, July 29, 2000; and "China Allotted 200 Million Yuan for Students Returned from Overseas," *People's Daily*, January 22, 2002.

[4] Cong Cao, Richard P. Suttmeier, and Denis Fred, "China's 15-Year Science and Technology Plan," *Physics Today* 59, no. 12 (2006): 38–43.

the "importance of genomics, proteomics, sequencing, and discovery of the functions of genes," all aspects that may be enhanced by contributions from artificial intelligence (AI).

Precision Medicine Initiative.[5] China's Precision Medicine Initiative (*Jingzhun yiliao jihua*), launched in 2016, seeks to leverage the country's sequencing capacity and access to biomedical data to design unique and tailored therapeutics for individuals and explore diseases endemic to China. This effort brings together information technology and biotech companies with Chinese government support ($9.2 billion) to design and apply new AI-enabled tools that analyze genomic, health, environmental, and behavioral data for insights into human health and therapeutics. It is modeled after an initiative launched by the United States in 2015.

13th Five-Year Plan for S&T Innovation.[6] The 13th Five-Year Plan (2016–20) introduces the relevance of AI to biotechnology, experimental design, and precision medicine. It further emphasizes the importance of interdisciplinary research and computing power: "Build high-throughput calculation, high-throughput experiment, and dedicated database platforms, research and develop the four key technologies of multi-level and cross-scale design, high-throughput preparation, high-throughput characterization and service evaluation, and material big data, achieve the transition of new materials R&D from the traditional 'experience-guided experiment' model to the 'theoretical prediction, experimental verification' model."[7] The plan also underscores the importance of genomic data to biotechnology and reiterates government plans for national-level genome databases by setting the following goals:

- "Establish a national bioinformatics and sample resource database, research and develop a number of suitable basic technologies and innovative products, comprehensively improve the level of birth defect prevention and control technology, safeguard the reproductive health of the reproductive age population, and improve the quality of the birth population."
- "Accelerate breakthroughs in cutting-edge key technology in life sciences such as new genomics technologies, synthetic biotechnology, biological big data, 3D bioprinting technology, brain science and artificial intelligence, gene editing technology, and structural biology."
- "Improve the originality of cutting-edge biotechnology in China, and seize a commanding position in international biotechnology competition."[8]

13th Five-Year Special Plan for S&T Military-Civil Fusion Development.[9] This plan was established in 2017 and focuses on emerging technologies. It calls specifically for a cross-pollination of military and civilian technology in areas not traditionally viewed as "national security issues," such as neuroscience and brain-inspired research, as well as biotechnology. The military-civilian fusion plan states that such projects will be supported by foreign outreach initiatives.

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5 Brian Wang, "China's $9.2 Billion Precision Medicine Initiative Could See about 100 Million Whole Human Genomes Sequenced by 2030 and More If Sequencing Costs Drop," NextBIGfuture.com, June 7, 2016; and David Cyranoski, "China Embraces Precision Medicine on a Massive Scale," *Nature* 529 (2016): 9–10.

6 State Council (PRC), "Guowuyuan guanyu yinfa shisanwu guojia keji chuangxin guihua de tongzhi" [13th Five-Year Plan for S&T Innovation], 2016.

7 "Translation: State Council Notice on the Publication of the National 13th Five-Year Plan for S&T Innovation."

8 Ibid.

9 Ministry of Science and Technology (PRC), "'Shisanwu' keji junmin ronghe fazhan zhuanxiang guihua" [13th Five-Year Special Plan for S&T Military-Civil Fusion Development], 2017.

14th Five-Year Plan.[10] China's latest five-year plan (2021–25) continues to emphasize interdisciplinary research and the use of AI for biological discovery and precision medicine. The plan underscores the importance to China of merging AI and biotechnology, as well as the need for both political and financial support: "We will promote the integration and innovation of biotechnology and information technology, accelerate the development of biomedicine, bioengineered breeding, biomaterials, bioenergy, and other industries and increase the size and strength of the bio-economy."[11]

Strategic emerging industries. China has designated several fields as "strategic emerging industries" (*zhanlue xing xinxing chanye*) to foster a more entrepreneurial environment and grow indigenous companies. The effort began at the top, spearheaded in 2009 by Wen Jiabao and the State Council,[12] and included preferential tax treatment, subsidies, and government procurement initiatives. AI and biotechnology are both considered strategic emerging industries and factor heavily into China's efforts.[13] In 2021, China doubled down on its policy to emphasize "key investments in strategic areas," create "industrial clusters," and accelerate the pace of innovation and development in the biotechnology industry.[14]

As a result of this multidecade effort and ample investments, China is having success in many areas and is currently creating a "biotech hub" that will support its success in the race from genotype to phenotype. The following examples show how China's biotechnology ecosystem has grown over the last decade.

The BGI Group is a Shenzhen-based gene-sequencing company with a global network of more than one hundred subsidiaries.[15] Its growth and success demonstrate how sustained support can affect a key emerging industry. BGI's collaborations give the company—and China—access to genomic data worldwide.[16]

Novogene is a genomic services provider that claims to have the world's largest sequencing capacity.[17] Its founder, Li Ruiqiang, was a senior executive at BGI and is an expert in genomics. Novogene has received investments from state-owned entities, including China Merchants

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[10] National People's Congress and Chinese People's Political Consultative Conference (PRC), "Zhonghua renmin gongheguo guomin jingji he shehui fazhan di shisi ge wu nian guihua he 2035 nian yuanjing mubiao gangyao" [The 14th Five-Year Plan for the National Economic and Social Development of the People's Republic of China and the Outline of Long-Term Goals for 2035], March 2021, https://cset.georgetown.edu/publication/china-14th-five-year-plan.

[11] Ibid.

[12] Office of the State Council (PRC), "Wen Jiaobao zhuchi zhaokai sanci xinxing zhanlue xing chanye fazhan zuotanhui" [Wen Jiabao Hosted Three Emerging Strategic Industry Development Symposiums], September 22, 2009; and State Council (PRC), "Guowuyuan guanyu jiakuai peiyu he fazhan zhanlue xing xinxing chanye de jueding" [State Council Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries], 2010.

[13] National Development and Reform Commission (PRC), "Guanyu kuoda zhanlue xing xinxing chanye touzi peiyang zhuangda xin zengzhang dian zengzhang ji de zhidao yijian" [Guiding Opinions on Expanding Investment in Strategic Emerging Industries, and Cultivating New Growth Points and Poles], 2020.

[14] "Translation: Outline of the People's Republic of China '14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035,'" CSET, Georgetown University, https://cset.georgetown.edu/publication/china-14th-five-year-plan; and State Council (PRC), "Guowuyuan guanyu yinfa shisanwu guojia zhanlue xing xinxing chanye fazhan guihua de tongzhi" [National 13th Five-Year Plan for the Development of Strategic Emerging Industries], 2016.

[15] The Beijing Genomics Institute, forerunner of the BGI Group, began in 1999 and continues some of its earlier activities in the Chinese Academy of Sciences as the Beijing Institute of Genomics. This essay uses the term "BGI" interchangeably to refer to the composite entities.

[16] Reuters reported that BGI used a military supercomputer to analyze genetic data obtained from its sales of prenatal tests to map the prevalence of viruses in Chinese women, look for indicators of mental illness, and genetically identify Tibetan and Uighur minorities. BGI has published at least twelve joint studies on the tests with the People's Liberation Army since 2010. See Kirsty Needham and Clare Baldwin, "Special Report: China's Gene Giant Harvests Data from Millions of Women," Reuters, July 7, 2021.

[17] Novogene, "About Us," https://en.novogene.com/about/about-novogene.

Bank (CMB), the CMB International Capital Corporation, and the State Development and Investment Corporation.[18]

Hong Kong–based Insilico Medicine, whose motto is “Artificial intelligence for every step of pharmaceutical research and development,”[19] has emerged as another major player in AI and biotechnology research in China. The company claims that its use of AI in pharmaceutical development reduced a multiyear discovery process costing hundreds of millions of dollars to eighteen months at a fraction of the cost.[20]

NeoX, a Beijing-based company, is another example of a multidisciplinary approach to AI and biotechnology. Co-founded by MIT and Caltech graduates, it seeks to use AI to shorten the timeline for pre-clinical drug design.[21] The company has what it describes as a unique and cutting-edge platform to screen candidates and simulate the directed evolution of biomolecules.

The Chinese Academy of Sciences’ Institute of Computing Technology (ICT) combines AI and medical research at its Bioinformatics Research Group and the Medical Imaging, Robotics, Analytical Computing Laboratory and Engineering. The former is housed under ICT’s Advanced Computing Research Laboratory, while the latter is a subdivision of ICT’s Key Laboratory of Intelligent Information Processing.

Shanghai Jiao Tong University’s Artificial Intelligence Institute houses the Center for Smart Healthcare, which aims to “empower clinical medicine and medical services with AI technology,” researches “new paradigms of human-machine interaction,” and develops “deep learning services for clinical diagnosis.” The center applies AI to disease prediction and a variety of health-related tasks.[22]

Nankai University College of Artificial Intelligence hosts the Tianjin Municipal Key Laboratory of Intelligent Robotics. R&D conducted at this laboratory includes medical and service robotics (surgery and rehabilitation support), brain-computer interfaces, and micro and nano detection for life sciences.[23]

Leveraging Global Biotechnology Collaborations

No treatment of Chinese S&T is complete without an examination of China’s state and corporate efforts to acquire foreign technology and technological know-how, especially from the United States. While China has made great strides in its domestic biotechnology capabilities and development strategies, as articulated in policy documents and their implementation notifications, central government policies that incentivize companies and individuals to return to China or transfer technology remain a key component of its efforts to dominate the field. In particular, the nexus of AI and biotechnology is a relatively immature area with cutting-edge work taking place in academia or corporate labs, is early in its development cycle, and is frequently beyond the scope of traditional counterintelligence mitigation strategies. This work is often funded by U.S. government agencies and departments, including those in the Department of Defense.

18 “Novogene,” Crunchbase, https://www.crunchbase.com/organization/novogene-corporation/company_financials.

19 Insilico Medicine, https://insilico.com.

20 Emma Betuel, “AI Drug Discovery Platform Insilico Medicine Announces $255 Million in Series C Funding,” TechCrunch, June 22, 2021, https://techcrunch.com/2021/06/22/a-i-drug-discovery-platform-insilico-medicine-announces-255-million-in-series-c-funding.

21 “AI-Driven Biotech Company neoX Raises $10M Pre-A Round,” July 6, 2020, China Money Network, https://www.chinamoneynetwork.com/2020/07/06/ai-driven-biotech-company-neox-raises-10m-pre-a-round.

22 Center for Mathematics of Artificial Intelligence Institute, Shanghai Jiao Tong University, https://ai.sjtu.edu.cn/center.

23 College of Artificial Intelligence, Nankai University, https://ai.nankai.edu.cn/xszx/tjsznjqrjszdsys.htm.

The following examples and case studies in the AI-biotech sector demonstrate how China leverages its own talent programs, domestic funding, and market access to both acquire technology in the short term and develop domestic capabilities in the long term. Taken individually, these examples are only anecdotal; however, taken together, they fit squarely into the programs and policies that China has implemented to build this prioritized field and tell a story of how a long-term strategy that has unfolded over a period of decades rather than years creates a blueprint for success.

ZhenFund is an early-stage investor, whose leadership partners with PRC state-sponsored talent programs and start-up contests. ZhenFund has invested in numerous AI companies, some of which are in the biotech space. These include SYNYI-AI, a smart hospital solutions provider; Deep Intelligent Pharma, a firm pursuing pharmaceutical discovery and development through AI; and CareAI Co. Ltd., a bioinformatics technology and high-performance computing company.

AI-biotech firm XtalPi Technology, based in China with a Boston branch, also received investments from Zhenfund after winning a cash prize at the Harvard College China Forum Pitch Competition.[24] XtalPi provides drug R&D services for pharmaceutical firms using computational physics, quantum chemistry, AI, and cloud computing.[25] All three of its co-founders were MIT postdoctoral researchers who were subsequently recruited through PRC talent programs.[26]

China's National Genomics Data Center, founded in 2019, benefits from Chinese scientists who have returned to China from abroad and who have direct experience in leading U.S. universities and the NIH.[27] The center acts as a clearinghouse for China's genetic data, with a genome-sequencing archive and branches with portfolios in precision medicine and agriculture. Many of its leading scientists have trained abroad and are members of China's various talent programs, often while still employed by their Western university. One of its leading scientists was selected for the Chinese Academy of Sciences 100 Talents Program while still working at the NIH.

BIAI Inc. was founded by Li Xiaotao, a former postdoctoral researcher at MIT, with the assistance of the Shenzhen municipal government's talent program known as the Peacock Plan. BIAI, which stands for "biological intelligence and artificial intelligence," has offices in both Massachusetts and Shenzhen and "relies on the technology platform of MIT and the Chinese Academy of Sciences." The company develops brain-computer interactions and supports treatment of brain disorders using data algorithms and smart wearable devices.[28]

An early returnee who has influenced how newer Chinese researchers are being trained is Rao Yi. His lab investigates the underlying behavior and cognition of molecular and cellular mechanisms, and he credits the importance of interdisciplinary work for his success.[29] Rao was a member of the inaugural group of recruits for China's Thousand Talents Program, returning to the country in 2007. He is currently the president of Capital Medical University in Beijing and previously served as the dean of sciences at Peking University and founding director of the PKU-IDG/McGovern Institute for Brain Research, among other high-ranking posts.

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24 "Pitch Competition," Harvard College China Forum, https://www.harvardchina.org/pitch.

25 "About Us," XtalPi, https://www.xtalpi.com/en/about.

26 See "Jingtai Technology Wen Shuhao: What Google Is Interested In Is the Core of Our Physical Bottom Layer (Interview)," DeepTech Deep Technology, May 17, 2020, https://zhuanlan.zhihu.com/p/141693312; and "About Us," Jingtai Technology, https://www.jingtaikeji.com/zh-hans/about.

27 "About," China National Genomics Data Center, https://ngdc.cncb.ac.cn/about.

28 See BIAI Inc., https://www.liepin.com/company/12926211.

29 "The Charm of Interdisciplinary Studies: Rao Yi's Interdisciplinary Views on Brain Research," Peking University News, June 4, 2020, https://newsen.pku.edu.cn/news_events/news/focus/9857.htm.

Finally, research documents how China's technology-transfer professionals, the so-called S&T diplomats (*keji waijiaoguan*), broker technology-transfer deals and coordinate with overseas experts to fulfill technology wish lists for Chinese entities.[30] These findings demonstrate the comprehensive and coordinated nature of China's effort to target technology globally. More than half of the 642 projects examined in the study were biotechnology or AI projects.

A Look Ahead: Areas for the United States and Like-Minded Countries to Consider

China has made academia and commerce its new geopolitical battlespace and has prioritized dominating biotech and the global pharmaceutical industry. If past actions are a guide, this goal will be achieved by targeting the early stages of cutting-edge research, acquiring companies with key technology, and becoming a chokepoint for pharmaceutical ingredients or generic medicines. China's focus on investment—over $100 billion since 2013—and acquisition of massive amounts of genomic and health data has put the country in the position to take the lead in this key technology field, which will have huge security and economic implications for decades to come. China's success highlights the limitations of relying on market-driven developments for key technologies when a strategic competitor has made the development of those technologies a formal strategic goal and supports "national champion" companies that do not have to make market-based decisions. In considering the future of biotechnology, the following areas will be essential for the United States and like-minded countries to explore.

Bio Rules of the Road

The United States and like-minded countries need to drive policies that include re-examining the "biological rules of the road" that govern the use and storage of genomic data, genomic editing, and animal models. In the aftermath of the Covid-19 pandemic, these policies should include discussions regarding the sharing of clinical and environmental samples, genomic data, and testing results.

It will be increasingly important to maintain transparency, reciprocity, and robust discussions of global norms related to the different aspects of biotechnology, including gain-of-function research, genomic security and privacy, the use of non-human primates, the editing of human embryos, and population surveillance. It will be important to ask the hard questions and—in the spirit of true collaboration—expect real answers. In addition, data privacy and data security will become increasingly important as more genomic and other biological information becomes available. There must be an open and difficult discussion on what is at stake. How do we maximize discovery but protect this resource, especially when others do not play by the same rules for sharing and collaboration?

Strategic Investments

The United States, its allies, and like-minded nations need to invest in—and strategically protect—infrastructure that supports the bioeconomy, such as sequencing capabilities, computing infrastructure, and diagnostic tool development, as a way to ensure that data and knowledge

[30] Ryan Fedasiuk, Emily Weinstein, and Anna Puglisi, "China's Foreign Technology Wish List," CSET, Georgetown University, May 2021.

discovery is not outsourced and lost to strategic competitors. The ability to drive medical research, provide and control medicines, ensure adequate food supplies, and tackle climate change will become more dependent on genomic data, specifically designed computing power, and access to animal models, including non-human primates.

Sequencing capacity based in the United States and U.S. allies that can be used by researchers and clinicians could support both research and clinical developments while safeguarding genomic resources. Moreover, it is not enough to only increase spending. The U.S. government and its allies should study what foundational investments are needed to support future discovery.

Supply Chain Security

Supply chains should be a key part of any bio-related strategy. Policymakers should undertake a detailed sketch of the human capital and supply chains needed to support research and industry development today and in the future. Too often, policy recommendations and research projects are focused on a snapshot in time and do not take into account the foundational parts of an industry that are not the most cutting-edge. The ability to manufacture the wide range of materials needed to support biological discovery and human and animal health is a key part of leading in this area.

In particular, items as basic as laboratory chemicals, active pharmaceutical ingredients, and supplies should not be forgotten in this discussion. China targets not only cutting-edge technologies but also key products on which the world is dependent. The last U.S. manufacturer of penicillin went out of business after China dumped chemicals on the market at low prices for four consecutive years. The Chinese government in this case filed a brief saying that the companies had to set prices low because of China's law.[31]

Research Security

Research security measures and risk mitigation should be part of R&D investments from their inception. These guiderails will foster collaboration and help ensure that the United States and its allies benefit from strategic investments. If biotechnology is truly a national security issue, the United States should decide which partners it wants to work with, define the parameters for sharing information, and then build appropriate cybersecurity measures into these projects. While it is important to reaffirm the value of open science, we must also acknowledge the costs of the theft of intellectual property, lack of transparency, and violations of existing agreements for the global norms of science. There are some parts of the development cycle where existing tools, such as export controls and sanctions, are a workable strategy. However, given that what is being targeted is often pre-commercialized, the United States must work with its allies and other like-minded countries to find new tools to mitigate China's acquisition strategies. Recent efforts across the U.S. government such as the National Science Foundation's SECURE Center and the Department of Energy's Research, Technology, and Economic Security Office are a start. Key will be acknowledging how China's system affects risk because it blurs the lines between civilian and military, public and private.

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[31] *Animal Science Products, Inc. v. Hebei Welcome Pharmaceutical Co. Ltd.*, 138 S. Ct. 1865 (2018). The slip opinion of the U.S. Supreme Court is available at https://www.supremecourt.gov/opinions/17pdf/16-1220_3e04.pdf.

THE NATIONAL BUREAU *of* ASIAN RESEARCH

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The Importance of Genomic Data for China's Global Health Ambitions

Caroline Schuerger and Anna Puglisi

CAROLINE SCHUERGER was previously a Research Fellow at Georgetown's Center for Security and Emerging Technology from 2021 to 2023.

ANNA PUGLISI is a Visiting Fellow at Stanford University's Hoover Institution. She can be reached at <annabp@stanford.edu>.

EXECUTIVE SUMMARY

This essay explores the use of genomic data and artificial intelligence in healthcare, addresses how China will be able to drive its bioeconomy with this data, and discusses the security implications of these capabilities.

MAIN ARGUMENT

China has made genomics a national priority and treats its genomic data as a strategic resource, which has several national security implications for the U.S. The Chinese government has created an R&D ecosystem where genetic data fuels the development of biotechnology applications, including public health and biodefense, medicine, and agriculture and food security. The rapid development of artificial intelligence in genomics facilitates large-scale data processing and utilization. China's generation, accumulation, and utilization of genetic data is aided by central policy planning in health-specific and R&D policy areas and is translating into global leadership in genomics. China is amassing large amounts of genomic data by leveraging its collaborations with foreign entities, while at the same time prohibiting external access to its genomic data.

POLICY IMPLICATIONS

The accumulation and utilization of genetic data by China, and its subsequent global leadership in genomics, has several policy implications for the U.S., particularly the Department of Defense:

- *Translating R&D into applications*. By harnessing the acquisition process, the Department of Defense could support not just precision medicine but the multiple areas that the new technology will touch.
- *Supporting the research base*. The Department of Defense could invest in and support not only the development but the manufacturing of equipment necessary to conduct genomic research.
- *Securing military service members' genomic data*. The Department of Defense should prioritize protecting the genomic data of service members, their families, and civilian employees so that it cannot be exploited by foreign entities.
- *Confronting ethical dilemmas*. Genomic technologies can be used in ways that the U.S. would consider unethical. Understanding the depth and breadth of research globally and discussing ways with allies and like-minded countries to regulate it and develop countermeasures will ensure that the U.S. is better prepared for the misuse of genomic research.

China and the world in general are on the cusp of game-changing discoveries in biotechnology driven by advances in artificial intelligence (AI). These applications include identification of drug targets, image screening, and predictive modeling of proteins and nucleic acids. AI facilitates the processing of vast amounts of experimental health and environmental data generated by today's researchers and supports an understanding of this data. Its use in basic research promises to shorten research timelines, enable analysis that was previously impossible, and open new fields of research.

This essay explores how China has made genomics a national priority and treats its genomic data as a strategic resource. China is amassing large amounts of genomic data by leveraging its collaborations with foreign entities, while at the same time prohibiting external access to its genomic data. The essay will explore the use of genomic data and AI in healthcare, address how China will be able to drive its bioeconomy with this data, and discuss the security implications of these capabilities.

China's leadership in genomics will have strategic implications for U.S. national security across a wide range of areas, including traditional biodefense, health, and the environment. Given the dual-use nature of these developments, together with China's civil-military fusion policy, growth in the bioeconomy will drive future applications of genomics, not only leading to new developments in personalized medicine but also enabling new defense applications. These include human performance modification, manipulation of the genome of select agents and other pathogens, and surveillance. Genomic data will be central to this process.

Applications of Genomics: The Race from Genotype to Phenotype

Perhaps no other part of biology holds such promise as the understanding of what genes do; scientists can harness that knowledge to understand human and organism traits, discover the causes of diseases, and use these findings for a wide range of applications. Since the completion of the Human Genome Project in 2001, access to genomic data has dramatically increased, with scientists gaining global access to DNA sequences, or genetic data, for almost every organism. The introduction of next-generation technologies, such as AI and machine learning, has the potential to accelerate not only the elucidation of what genes do but also the development of applications that would have taken previous researchers decades to discover.

What Areas Will Be Affected by These Developments?

Public health and biodefense. Tracking and monitoring pathogens via their genetic sequence is important for public health outbreak response and key aspects of biodefense, both domestically and for force protection.[1] Genomic data is an essential piece of this puzzle because it enables detection and monitoring, as well as the development of therapies and medical interventions. Examples include the following:

- Influenza surveillance uses genetic sequencing to monitor flu strains in both humans and animals to determine the transmission of potential outbreaks, predict emerging variants, and prepare vaccinations.[2]

[1] "Coronavirus Disease 2019 (COVID-19)," CDC, February 11, 2020, https://www.cdc.gov/coronavirus/2019-ncov/science/about-epidemiology/monitoring-and-tracking.html; and "What Is Case Surveillance?" CDC, August 15, 2022, https://www.cdc.gov/nndss/about/index.html.

[2] "Influenza Virus Genome Sequencing and Genetic Characterization," CDC, November 2, 2021, https://www.cdc.gov/flu/about/professionals/genetic-characterization.htm.

- Wastewater surveillance for Covid-19 tracks community spread and the emergence of additional variants.[3]
- Surveillance of animal diseases mitigates consequences of major livestock outbreaks that could affect food supply chains.[4]
- Sequencing of anthrax samples (such as those used in the 2001 anthrax attacks) helps determine if they are of the same strain and thus originate from a single source.[5]

Medicine. Genetic data can be used to diagnose and understand diseases as a way to develop new therapies and next-generation medical technologies. Some examples are the following:

- Radiologists use neural networks to determine best treatments based on a patient's genetic data and to interpret medical images and scans like X-rays or MRIs.[6]
- Clinicians use AI tools to diagnose and classify cancer by discovering patterns in genetic mutations and even predict the risk of hospital readmission.[7]
- Researchers at the Mayo Clinic developed an algorithm to predict outcomes from chemotherapy or immunotherapy for gastric cancer patients depending on their genetic mutations.[8]

Access to genomic data will provide an advantage due to its role in drug discovery, diagnostics, and clinical trials. These resources will continue to enable future discoveries that directly affect the bioeconomy.

Agriculture and food security. Conflict over resources such as food and energy are likely to increase with climate change.[9] Access to and understanding of plant and animal genomes will enable scientists to increase crop yields, protect against disease, and find new sources of energy while countries adjust to a changing climate. Some examples include the following:

- As part of new initiatives on clean energy, plants such as corn have already been genetically altered to produce a protein that helps convert the corn's cellulose into a fuel.[10]
- Plants are often modified to increase nutritional value. Golden rice, for example, was genetically modified to increase vitamin A content.[11]

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3 "National Wastewater Surveillance System," CDC, May 16, 2022, https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/wastewater-surveillance.html.

4 "Animal Health Surveillance in the United States," U.S. Department of Agriculture, Animal Plant and Health Inspection Service, https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance.

5 Alex R. Hoffmaster et al., "Molecular Subtyping of Bacillus Anthracis and the 2001 Bioterrorism-Associated Anthrax Outbreak, United States," *Emerging Infectious Diseases* 8, no. 10 (2002): 1111–16.

6 Eric J. Topol, "High-Performance Medicine: The Convergence of Human and Artificial Intelligence," *Nature Medicine* 25, no. 1 (2019): 44–56.

7 Shamsul Masum et al., "Data Analytics and Artificial Intelligence in Predicting Length of Stay, Readmission, and Mortality: A Population-Based Study of Surgical Management of Colorectal Cancer," *Discover Oncology* 13, no. 1 (2022): 11.

8 Jae-Ho Cheong et al., "Development and Validation of a Prognostic and Predictive 32-Gene Signature for Gastric Cancer," *Nature Communications* 13, no. 1 (2022): 774.

9 Office of the Director of National Intelligence, "2022 Annual Threat Assessment of the U.S. Intelligence Community," March 8, 2022, https://www.dni.gov/index.php/newsroom/reports-publications/reports-publications-2022/item/2279-2022-annual-threat-assessment-of-the-u-s-intelligence-community.

10 "Corn Primed for Making Biofuel," *MIT Technology Review*, https://www.technologyreview.com/2008/04/16/269967/corn-primed-for-making-biofuel; and U.S. Department of Energy, *Basic Research Opportunities in Genomic Science to Advance the Production of Biofuels and Bioproducts from Plant Biomass* (Washington, D.C., June 2015), https://genomicscience.energy.gov/white-paper-basic-research-opportunities-in-genomic-science-to-advance-the-production-of-biofuels-and-bioproducts-from-plant-biomass.

11 Genetically modified organisms (GMOs) address problems like malnutrition and hunger. For example, the scientists who genetically cross-bred wheat to resist bacteria were awarded the Nobel Peace Prize. Publicly available genomic databases of hundreds of plant species were created by the United States (https://data.nal.usda.gov) and other stakeholders (https://plants.ensembl.org) to accelerate R&D of GMOs for food and biofuels. Jacqueline A. Paine et al., "Improving the Nutritional Value of Golden Rice through Increased Pro-Vitamin A Content," *Nature Biotechnology* 23, no. 4 (2005): 482–87.

- Additional crops have been developed to resist insects and plant viruses and survive in drought conditions.[12]

Though there are numerous benefits to genetically modifying plants, there are also unintended consequences, such as adverse impacts on the natural ecological food chains.[13] Additionally, there are issues regarding regulations of food produced by GMOs as well as issues related to the intellectual property of companies that develop GMO seeds.

How Do Governments and Companies Gain Access to Genomic Data Sources?

Genetic material can be easily collected from animals, plants, and organisms, including people. The United States just recently has begun to restrict access to biometric data, including genomic data.[14] Human genetic material can be obtained via a doctor's visit or a test for a disease sent to a private company, or from a database if the individual chooses to send data to a company to find out their genomic sequence. Many people do not realize that their medical tests and samples are often sent offshore or analyzed by a foreign company. Though the Health Insurance Portability and Accountability Act of 1996 (HIPAA) does protect against the disclosure of personal medical information, it does not prevent the sharing of anonymized samples.[15] This exception has far-reaching implications for U.S. military personnel and their families because genomic data can provide personal details about individual health and wellbeing, as well as provide an avenue for more extensive surveillance of military personnel overseas. Hospitals, government clinics, and private companies, among other actors, are able to collect human genetic material from sources ranging from ancestry DNA and Covid-19 tests to blood and tissue samples. Many databases of genetic data are publicly or privately available. The National Institutes of Health maintains a gene bank of over 450,000 species in collaboration with the DNA DataBank of Japan and the European Nucleotide Archive.[16] The database is publicly available, meaning that anyone can download this data for their research. Yet while many countries contribute to such international public databases, China does not contribute to them or allow foreigners access to its own genetic data. In fact, Beijing recently passed a series of laws, discussed below, that prohibit the export of human genetic data. Therefore, Chinese researchers have access to not only the same genetic data that U.S. researchers do but also additional data collected in China that is not available to outside researchers.

Competition between the United States and China

Where the United States Stands

Whoever dominates the genomics space will control the development of next-generation medical technologies, research standards and norms, and future genomics applications. The

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[12] Jorge Fernandez-Cornejo et al., "Genetically Engineered Crops in the United States," U.S. Department of Agriculture, Economic Research Report, http://www.ers.usda.gov/publications/pub-details/?pubid=45182.

[13] Theresa Phillips, "Genetically Modified Organisms (GMOs): Transgenic Crops and Recombinant DNA Technology," *Nature Education* 1, no. 1 (2008): 213, http://www.nature.com/scitable/topicpage/genetically-modified-organisms-gmos-transgenic-crops-and-732.

[14] Executive Office of the President, "Preventing Access to Americans' Bulk Sensitive Personal Data and United States Government-Related Data by Countries of Concern," Executive Order, no. 1477, February 28, 2024, https://www.federalregister.gov/documents/2024/03/01/2024-04573/preventing-access-to-americans-bulk-sensitive-personal-data-and-united-states-government-related.

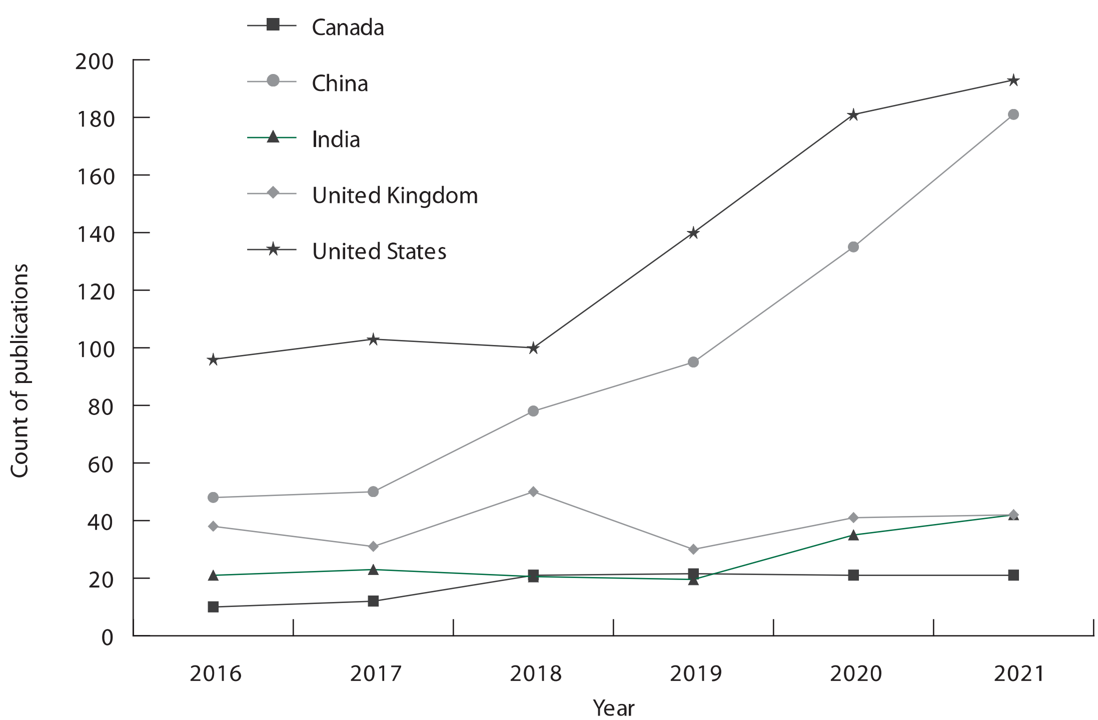
[15] Since each person's DNA is unique, genomic data can never truly be anonymous. Additionally, researchers are able to trace DNA samples back to the patient from whom they originated.

[16] National Library of Medicine, National Center for Biotechnology Information, "GenBank Overview," https://www.ncbi.nlm.nih.gov/genbank.

genomics part of the bioeconomy alone is estimated to have had an economic impact of over $265 billion in the United States since the completion of the Human Genome Project.[17] As a way to better understand the depth and breadth of research in this area, the Center for Security and Emerging Technology (CSET) investigated research output in the convergence of genetics and AI. Following a consistent exponential trend, China is catching up to the United States in producing publications with "genetics" and "AI" keywords (see **Figure 1**). Publications are an indicator of basic research output and give insight into how a country prioritizes fields of study.

Another CSET study examined publications with the keywords "CRISPR" and "AI" as well as "bio" and "AI" and found that China is also growing in these fields.[18] The authors discovered that the Chinese government established biomedical clusters to co-locate AI and biotechnology researchers to support developing next-generation research.[19] Publications with these keywords

FIGURE 1 Trends of the top five countries by count of research publications (y-axis) containing "genetics" and "AI" keywords



SOURCE: Emerging Technology Observatory, CSET, "Research Almanac." The Research Almanac sources metadata from its Merged Academic Corpus that contains detailed information on over 270 million scholarly articles. The Merged Academic Corpus is not publicly available due to licensing restrictions. Sources and methodologies are available at https://eto.tech/tool-docs/almanac/#sources-and-methodology.

17 Simon Tripp and Martin Grueber, "The Economic Impact and Functional Applications of Human Genetics & Genomics," American Society of Human Genetics, May 19, 2021, https://www.ashg.org/advocacy/the-economic-impact.

18 CRISPR (clustered regularly interspaced short palindromic repeats) is a gene editing technology that allows scientists to better understand what genes do. CRISPR+AI and Biology+AI publications are indicators of next generation technologies that integrate foundational basic research in genetics and biology for potential future use in the medical field.

19 Anna Puglisi and Daniel Chou, "China's Industrial Clusters: Building AI-Driven Bio-Discovery Capacity," Center for Security and Emerging Technology (CSET), Data Brief, June 2022, https://doi.org/10.51593/20220012.

are early indicators of the development of next-generation technologies that integrate foundational basic research in genetics and biology for potential future use in the medical field. China either leads or is in close competition with the United States in the field of applied genomics. For example, hospitals in both China and the United States are already using AI-enabled medical technologies that were developed using genomic data. The global DNA-sequencing market is expected to grow exponentially.[20] While the U.S.-based company Illumina develops new sequencing technologies that reduce the cost of sequencing even further,[21] China's MGI, a subsidiary of the Shenzhen-based BGI, also announced new sequencing technologies at competitive prices.[22] Illumina and MGI have long been embroiled in legal battles over patent infringement to the tune of hundreds of millions of dollars.[23]

The following section details the steps that Beijing took to become a lead competitor in genomics, in particular describing how the government views genetic data as a national strategic resource. As noted above, China views genomic data as key to understanding what genes do and developing future applications. While it collects data worldwide, China restricts access to its own genetic resources in order to maintain a competitive advantage.

How Did China Get Here?

China's generation, accumulation, and utilization of genetic data is facilitated by central policy planning in health-specific and R&D policy areas. These policies aim to apply genetic data to next-generation technological advancement, including AI, for several reasons:

- Facilitating disease surveillance, vaccine development, and public health.[24]
- Addressing barriers to healthcare, such as shortages of physicians and the lack of medical access in rural areas, and enabling personalized medical treatments.[25]
- Modifying food crops to feed China's population of one billion people.[26]

Beijing's major health policy is one of many that calls for the collection of human genetic data (see the **Appendix** for a full list). To address public health needs, the Healthy China 2030 Policy focuses on "promoting the construction of a healthy China" through reform and innovation, as well as scientific development.[27] Under this policy, the State Council aims to "realize data collection, integration, sharing, and business of public health," specifically by directing data collection to promote big data–informed health applications. Additionally, the policy aims to strengthen data

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[20] "DNA Sequencing Market to Generate Revenue of $29.89 Billion by 2028," GlobeNewswire, September 12, 2022, https://www.globenewswire.com/en/news-release/2022/09/12/2514305/0/en/DNA-Sequencing-Market-to-Generate-Revenue-of-29-89-Billion-By-2028-Demand-for-DNA-Sequencing-to-Increase-1200-if-Per-Genome-Sequencing-Goes-Down-to-100.html.

[21] "Illumina Introduces Multiple Breakthrough Sequencing Innovations at Inaugural Genomics Forum," Illumina, Press Release, September 29, 2022, https://www.illumina.com/company/news-center/press-releases/press-release-details.html?newsid=0ecd2346-d78b-4d06-be9f-27364492c2ee; and National Human Genome Research Institute, "DNA Sequencing Costs: Data," May 16, 2023, https://www.genome.gov/about-genomics/fact-sheets/DNA-Sequencing-Costs-Data.

[22] Huanjia Jhang, "MGI Tech Launches New Ultra-High-Speed, Mid-to-Low throughput Sequencer," GenomeWeb, September 27, 2022, https://www.genomeweb.com/sequencing/mgi-tech-launches-new-ultra-high-speed-mid-low-throughput-sequencer.

[23] Blake Brittain, "BGI Group Units, Illumina Settle U.S. Lawsuits over DNA Sequencing," Reuters, July 14, 2022, https://www.reuters.com/legal/litigation/bgi-group-units-illumina-settle-us-lawsuits-over-dna-sequencing-2022-07-14.

[24] Ting Wang et al., "Artificial Intelligence Against the First Wave of COVID-19: Evidence from China," *BMC Health Services Research* 22, no. 1 (2022): 767.

[25] Sarah O'Meara, "China's Data-Driven Dream to Overhaul Health Care," *Nature*, https://www.nature.com/articles/d41586-021-02694-1.

[26] Dominique Patton, "China to Allow Gene-Edited Crops in Push for Food Security," Reuters, January 25, 2022, https://www.reuters.com/world/china/china-drafts-new-rules-allow-gene-edited-crops-2022-01-25.

[27] State Council of the People's Republic of China (PRC), "Healthy China 2030 Policy," November 16, 2016, https://web.archive.org/web/20161115230721/http:/news.xinhuanet.com/health/2016-10/25/c_1119786029.htm.

exchanges, eliminate data barriers, and establish data-sharing mechanisms to promote progress in precision medicine and smart medicine. China has reportedly budgeted over $9 billion for its Precision Medicine Initiative under Healthy China 2030 and established a national gene bank to maintain databases of genetic resources.[28] The government-owned and -funded China National GeneBank (CNGB), established in 2011, "facilitate[s] advanced genomics R&D and technology transfer to industrial application, including precision medicine."[29] Programs like the CNGB enable massive data collection, storage, and sharing of millions of genetic samples within China. Beijing now requires hospitals to digitize health records and provide universal digital healthcare, driving further collection of health data.[30] Together, these policies demonstrate the Chinese government's commitment to collecting health data across a spectrum of healthcare issues. In Xinjiang, for example, the Population Registration Program's Physicals for All initiative has collected data from over 20 million people.[31] China's collaborations in Africa and South Asia likewise give the country access to a wide range of human, animal, and plant genomes.[32]

The Chinese government has created an R&D ecosystem where collected genetic data fuels the development of biotechnology applications. Its goal is to transform China from a biotech power (*shengwujishu daguo*) to a biotech superpower (*shengwujishu qiangguo*).[33] Every major policy planning document emphasizes succeeding in biotechnology, including the five-year plans and the National Medium- and Long-Term Plan for Science and Development (see Appendix). Specific AI-development plans encourage universities and institutions to integrate AI into biomedical research and healthcare in order to further basic research in these areas. Additionally, the central government supports major biomedical "champions" (i.e., favored state and private companies). BGI, for example, received $1.5 billion from the China Development Bank, which funded its purchase of Illumina sequencers. BGI also partners with the government in the CNGB.[34]

Infrastructure for genetic-AI research and data instituted by Beijing includes the following:

- State-sponsored "key laboratories" dedicated to AI and medicine, including the Key Laboratory of Medicine AI Research and the Key Laboratory of Big Data–based Precision Medicine.[35]
- "Industrial clusters" that co-locate universities, institutes, and companies to "accelerate the pace of innovation and development in the biotechnology industry."[36] These clusters include facilities for medicine and AI, such as Shanghai Jiaotong University's Artificial Intelligence Institute, which houses the Center for Smart Healthcare.

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28 David Cyranoski, "China Embraces Precision Medicine on a Massive Scale," *Nature* 529, no. 7584 (2016): 9–10.

29 National Genomics Data Center webpage, https://ngdc.cncb.ac.cn/about.

30 "14th Five-Year Plan for National Informatization," trans. DigiChina Project, December 2021, https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021.

31 Emile Dirks and James Leibold, "Genomic Surveillance: Inside China's DNA Dragnet," Australian Strategic Policy Institute, International Cyber Policy Centre, Policy Brief, June 2020, https://ad-aspi.s3.ap-southeast-2.amazonaws.com/2020-06/Genomic%20surveillance_1.pdf?VersionId=QhPFyrNVaSjvblmFT24HRXSuHyRfhpml.

32 "China-Funded Research Center to Boost Africa's Biodiversity Conservation," Chinese Academy of Sciences, August 3, 2015, https://english.cas.cn/newsroom/archive/news_archive/nu2015/201508/t20150803_151038.shtml.

33 State Council (PRC), "State Council Notice on the Publication of the National 13th Five-Year Plan for S&T Innovation," trans. CSET, July 28, 2016, https://cset.georgetown.edu/publication/state-council-notice-on-the-publication-of-the-national-13th-five-year-plan-for-st-innovation.

34 "BGI to Receive $1.5B in 'Collaborative Funds' over 10 Years from China Development Bank," GenomeWeb, January 12, 2010, https://www.genomeweb.com/sequencing/bgi-receive-15b-collaborative-funds-over-10-years-china-development-bank.

35 Emily Weinstein et al., "China's State Key Laboratory System: A View into China's Innovation System," CSET, Data Brief, June 2022, https://doi.org/10.51593/20210019.

36 Puglisi and Chou, "China's Industrial Clusters: Building AI-Driven Bio-Discovery Capacity"; and State Council (PRC), "National 13th Five-Year Plan for the Development of Strategic Emerging Industries," trans. CSET, November 29, 2016, https://cset.georgetown.edu/research/national-13th-five-year-plan-for-the-development-of-strategic-emerging-industries.

- The National Genomics Data Center, which allows researchers to access genomic data for several organisms, including rice, sheep, and humans, to further develop AI-enabled medical technologies.[37]

China's medical device policies incentivize companies to use genetic data to develop and deploy AI-enabled medical technologies. The National Medical Products Administration (NMPA), China's medical device and drug approval agency, updated its regulations, expanding the scope from "data from medical devices" to encompass medical and nonmedical information, including genetic data, medical records, exam results, and patient complaints.[38] This guidance also reduced certification processing time and increased the length of service certification. The revised NMPA regulations open the door for Chinese companies to use wider sources of genetic data in their medical technologies and reduce bureaucratic barriers to applying for certification.

Crucially, the policies and regulations that allow the Chinese government to connect and generate massive amounts of data also prevent that data from leaving China. Privacy and security laws (see Appendix) explicitly state that foreign entities cannot use genetic data without approval or export the data outside China. Such policies suggest that the Chinese Communist Party views its massive data collection capabilities as a competitive advantage in medicine and technology development relative to foreign countries.

Implications: The Future Outlook

China is already a major player in the field of genomics—both in applying current genomic technologies and in developing new capabilities. Evidence indicates that its capabilities are growing exponentially in these areas, and dozens of policies dedicated to the collection and use of genetic data demonstrate Beijing's long-term prioritization of genomics. The consequences of China dominating the field span a wide range of issues of interest not only to the U.S. Department of Defense but to U.S. national security more broadly. This section surveys areas that will affect the Department of Defense's missions and considers potential remedies.

Freedom of movement. China currently exports surveillance and security technologies globally, and Chinese companies are increasingly the vendor of choice for port, airport, and border surveillance.[39] China's national biomedical "champions" are beginning to be included in Belt and Road Initiative (BRI) projects. At home, Chinese authorities collect genetic data by force,[40] and studies by Chinese researchers highlight an attempt to try to identify ethnic minorities based on their DNA.[41] Though the technology may not currently exist, these steps taken by China clearly demonstrate its goal to integrate genomics into surveillance. The implications for the U.S. Department of Defense include the following:

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37 National Genomics Data Center webpage, https://ngdc.cncb.ac.cn/about.

38 China National Medical Products Administration, "Guidelines for the Registration and Examination of AI Medical Devices," 2022, https://perma.cc/3VVC-7J3B.

39 Paul Mozur, Jonah M. Kessel, and Melissa Chan, "Made in China, Exported to the World: The Surveillance State," *New York Times*, April 24, 2019, https://www.nytimes.com/2019/04/24/technology/ecuador-surveillance-cameras-police-government.html.

40 Dirks and Leibold, "Genomic Surveillance."

41 Jing Jia et al., "Developing a Novel Panel of Genome-Wide Ancestry Informative Markers for Bio-Geographical Ancestry Estimates," *Forensic Science International: Genetics* 8, no. 1 (2014): 187–94.

- The heightened ability to track people and equipment could allow China to identify intelligence officers and, in times of crisis, provide it with an early warning of the movement of U.S. and allied forces and logistics.
- Access to genomic data from BRI projects will enhance China's ability to design surveillance systems and biometrics.

Force protection and healthcare. China currently has access to U.S. citizens' genomic data because its national biomedical champion companies provide diagnostic and testing services for U.S. hospitals, giving their researchers access to the genomic data they work with.[42] Additionally, many U.S. companies share genomic data that was used to develop their own technologies with Chinese counterparts as part of intellectual property–sharing agreements.[43] Both of these practices create dependencies in the U.S. medical system and also increase the risk of members of the U.S. military and their families being targeted because of healthcare issues or tracked based on genomic information.

Ethical asymmetries in R&D. As stated earlier, Chinese researchers have access to the same public data as researchers in the United States, as well as all the data collected within China that is not shared with foreign researchers. China also collects genomic data in ways that democratic societies deem unethical and that could provide it with advantages in certain aspects of biological discovery.[44] This includes the collection of data without consent from political prisoners and marginalized groups. China's security laws also dictate that private entities and universities must share all data when asked. The ability of Chinese scientists to work on research proscribed in other countries could lead to new breakthroughs in understanding pathogen-host interactions, human performance modification, and new forms of biological warfare, including bioregulators.

Supply chain. The United States is dependent on China for key links in its pharmaceutical and research supply chains.[45] These include components of pharmaceutical drugs, personal protective equipment, and reagents required for research experimentation. This reliance affects the Department of Defense's mission in very basic ways—such as lack of access to antibiotics—and poses future threats, including potential shortages of lab equipment that supports research. Chinese companies and subsidiaries of Western companies in China are often the sole providers of medicines, medical technologies, and basic disease-surveillance kits that U.S. hospitals—and the Department of Defense—depend on to save lives. China could stop the export of these services and materials, as it has in the past for rare earth metals, and bring both the U.S. medical and research systems to a halt. This risk may also carry broader implications for medical research, including into cures and treatments for diseases.

Preparing for the genomic future. The potential of genomic technology goes far beyond medical applications to offer solutions to the biggest challenges facing all societies in the 21st century, from the global climate crisis to food insecurity to materials that will transform industries and manufacturing at scale. How nations pursue the power to engineer living systems will reshape

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42 U.S.-China Economic and Security Review Commission, "China's Biotechnology Development: The Role of U.S. and Other Foreign Engagement," February 14, 2019, https://www.uscc.gov/research/chinas-biotechnology-development-role-us-and-other-foreign-engagement.

43 Kelsey Ketchum, "BGI Genomics Program Seeks to Validate Signatera Test for Colorectal Cancer Patients in China," GenomeWeb, October 28, 2021, https://www.genomeweb.com/cancer/bgi-genomics-program-seeks-validate-signatera-test-colorectal-cancer-patients-china.

44 Dirks and Leibold, "Genomic Surveillance."

45 Janet Woodcock, "Safeguarding Pharmaceutical Supply Chains in a Global Economy," testimony before the U.S. House Committee on Energy and Commerce, Subcommittee on Health, Washington, D.C., October 29, 2019, https://www.fda.gov/news-events/congressional-testimony/safeguarding-pharmaceutical-supply-chains-global-economy-10302019.

ways of life. Of particular significance is whether strategies reflect and reinforce the values of democratic societies. As discussed above, China seeks to protect its own genomic resources by limiting access to them, uses market access to obtain technology and know-how from foreign companies, and shows a willingness to conduct research proscribed in other countries. These practices lead to ethical asymmetries that could give China an advantage in the development of new technologies. Examples of China's controversial research practices include the following:

- The development of non-human primate colonies as countries across the rest of the world close theirs.[46]
- The collection of global genomic data and the development of infrastructure to collate and exploit it.[47]
- The gene editing of human embryos and subsequent birthing of the edited humans.[48]

The United States—and specifically the Department of Defense—must be positioned to harness these developments and ensure that applications reflect democratic values. The following are potential avenues for action:

- *Translating R&D into applications*. By harnessing the acquisition process, the Department of Defense could support not just precision medicine but the multiple areas that the new technology will touch.
- *Supporting the research base*. The Department of Defense could invest in and support not only the development but the manufacturing of equipment necessary to conduct genomic research.
- *Securing military service members' genomic data*. The Department of Defense should prioritize protecting the genomic data of service members, their families, and civilian employees so that it cannot be exploited by foreign entities.
- *Confronting ethical dilemmas*. Genomic technologies can be used in ways that the United States would consider unethical. Understanding the depth and breadth of research globally and discussing ways with allies and like-minded countries to regulate it and develop countermeasures will ensure that the United States is better prepared for its misuse.

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46 Dennis Normile, "China Bets Big on Brain Research with Massive Cash Infusion and Openness to Monkey Studies," *Science*, September 20, 2022, https://www.science.org/content/article/china-bets-big-brain-research-massive-cash-infusion-and-openness-monkey-studies.

47 Jessie Yeung, "China's Sitting on a Goldmine of Genetic Data—and It Doesn't Want to Share," CNN, August 12, 2023, https://www.cnn.com/2023/08/11/china/china-human-genetic-resources-regulations-intl-hnk-dst/index.html.

48 Dennis Normile, "CRISPR Bombshell: Chinese Researcher Claims to Have Created Gene-Edited Twins," *Science*, November 26, 2018, https://www.science.org/content/article/crispr-bombshell-chinese-researcher-claims-have-created-gene-edited-twins.

APPENDIX

TABLE 1 China's major health plans and policies

Plan/Policy	Year	Implications
Implementation Rules for the Regulations on the Management of Human Genetic Resources	2023	• Prohibits foreign entities and organizations from collecting and storing Chinese human genetic resources • Requires studies that collect Chinese human genetic resources to collaborate with a Chinese company or organization
Guidelines for the Registration and Examination of AI Medical Devices	2022	• Introduces a more detailed definition of allowed data sources for AI devices, expanding the scope from "data from medical devices" to encompass medical and nonmedical information, such as medical records, exam results, and patient complaints • Expedites process and certification length • Requires foreign entities to hire domestic registration agents tasked with overseeing the device registration process
14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035	2021	Sets the following goals: • Apply genetic research for technological innovations • Establish national laboratories with a focus on AI, biotechnology, and pharmaceuticals • Reorganize the state key laboratories to form a laboratory system • Name biotechnology a strategic emerging industry • Accelerate deployment of cutting-edge technologies
Personal Information Protection Law	2021	• Protects individuals' privacy by requiring consent to collect or process personal data, including medical and biometric information • Prohibits the transfer of personal data outside China
14th Five-Year Plan for National Informatization	2021	• Requires hospitals to digitize health records, including genetic data • Provides universal digital healthcare
New Chinese Ambitions for "Strategic Emerging Industries"	2020	Sets the following goals: • Accelerate the pace of innovation in the biotechnology industry • Establish biotechnology and pharmaceutical innovation centers • Create markets for pharmaceutical drugs and medical equipment
Biosecurity Law	2021 (drafted 2020)	• Strengthens the management and oversight of the collection, storage, use, and external provision of human genetic resources • Allows the government to "enjoy sovereignty" over human genetic resources and biological resources
Regulations on the Administration of Human Genetic Resources	2019	• Requires organizations to apply for a certification to use human genetic resources within China • Prohibits collection or preservation of human genetic resources by foreign organizations and individuals • Requires foreign organizations to have a domestic sponsor to apply or use any human genetic resources within China

Table 1 continued.

Plan/Policy	Year	Implications
Internet + Healthcare Initiative	2018	• Enhances public health services by integrating technology into hospitals and public health • Advances the "Internet +" initiative
AI Innovation Action Plan for Institutions of Higher Education	2018	• Promotes the deep integration of information technologies with modern biotechnology • Calls on universities to apply AI to intelligent medical care
New Generation Artificial Intelligence Development Plan	2017	• Directs organizations to develop new models and methods of AI in fields such as healthcare, precision medicine, and genetics
Precision Medicine Initiative	2016	• Funds a $9.2 billion, fifteen-year program to "build up the country's credentials in precision medicine" • Establishes precision-medicine centers between hospitals, universities, and gene-sequencing companies • Plans to sequence over 100 million human genomes to surpass the goal of the United States' Precision Medicine Initiative • Establishes a database of genomic data from Chinese and international populations
Healthy China 2030 Policy	2016	• Promotes the construction of a healthy China through reform, innovation, and scientific development • Collects, integrates, and shares data to promote big data–informed health applications
National 13th Five-Year Plan for S&T Innovation	2016	Sets the following goals: • Develop cutting-edge and general-purpose biotechnology, including gene editing and synthetic biology • Seize a commanding position in international biotechnology competition
National 13th Five-Year Plan for the Development of Strategic Emerging Industries	2016–20	Sets the following goals: • Accelerate development of genomics and associated technologies for use in precision medicine, biosynthesis, and agriculture • Promote disruptive technological innovation in agricultural biology • Promote the clinical application and industrialization of artificial biology and artificial biological devices
Made in China 2025	2015	• Promotes the integration of new-generation information technology and manufacturing, including into science and technology innovations like bioengineering
National Medium- and Long-Term Program for Science and Development	2006–20	• Prioritizes development of biotechnology and life sciences • Establishes mega-projects to meet China's development goals, including in public health and genetically modified agriculture • Calls for R&D of genome sequencing and genetic structure analysis • Calls for breakthroughs in the fields of functional genomics, proteomics, and stem cells, among others

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The Divergence in Non-human Primate Research between the United States and China: Causes and Implications

Rowan Pierson

ROWAN PIERSON is a JD candidate at the George Washington University Law School. He earned his AB in public and international affairs with highest honors from Princeton University, where he authored a senior thesis titled "The Strategic Importance of Monkeys: Divergence in Non-human Primate Research between the United States and China." He can be reached at <rowanp@alumni.princeton.edu>.

EXECUTIVE SUMMARY

This essay lays out the divergence in attitudes and approaches to non-human primate (NHP) research between the U.S. and China and considers the implications of the divergence for the future of U.S. biotechnology supremacy.

MAIN ARGUMENT

NHP research plays a crucial role in developing our understanding of the human brain, producing treatments for human diseases and disorders, and shaping the future of emerging technologies like gene-editing tools and artificial intelligence. While the U.S. has historically been the global leader in NHP research and the advancements resulting from it, current trends indicate that the situation is changing. China is investing substantially in expanding its own NHP research capacity, has a friendly environment for NHP research, has a public climate supportive of scientific investigation, and is actively prioritizing research primates as a strategic resource. In contrast, funding for NHP research in the U.S. has been stagnant for nearly two decades, there is an acute shortage of research primates, and there is substantial pressure to end primate research entirely. Given the importance of NHPs for scientific research, the current research trends taking place in the U.S. and China are of substantial strategic importance and serve as an excellent case study of the steps China is taking to rapidly usurp the U.S. as the global leader of R&D more broadly.

POLICY IMPLICATIONS

- In a future where NHPs continue to be an invaluable research model, China is likely to have an advantage over the U.S. moving forward in control over the validation of new therapeutics and the development of emerging technologies.
- However, through the refinement of NHP research techniques and the rapid development of new tools and methods to replace NHPs, it is possible that the United States could still compete with China for supremacy in NHP-reliant research fields using comparatively inferior resources.
- Regardless of whether a high- or low-utility NHP research scenario occurs, investment in alternative methodologies and creative solutions to limit China's advantage in NHP research could hold the key to helping the U.S. maintain its global science and technology supremacy.

The United States and China are diverging in their attitudes and approaches toward experimentation on non-human primates (NHPs). Scientific research involving primates may not be the first issue that comes to mind when thinking about control of future developments in vaccines, antibody/immune therapy, and treatment for neurodegenerative disorders; the race to understand the origin and emergence of human cognition; or the future of pharmaceutical development and emerging technologies like advanced artificial intelligence (AI). Primate research, however, plays a critical role in each of these areas. NHPs are singularly valuable models for understanding human disease and development because of their close phylogenetic relationship to humans and their sophisticated behaviors and cognition.[1] Therefore, NHPs and those who have access to them have the potential to determine not only where future discoveries in pharmaceutical development and biotechnology take place but also who controls the therapies, drugs, and intellectual property that are discovered. Thus, any divergence in NHP research between the United States and China is of substantial strategic importance.

Furthermore, the divergence taking place in NHP research between the United States and China serves as an excellent case study of the steps China is taking to rapidly usurp the United States as the global leader of R&D more broadly. China's ban on the export of NHPs, introduced in 2020 in response to the Covid-19 pandemic, sheds light on its activities to bolster its NHP research capacity and to transition from being a country that exports significant numbers of primates to one that uses them domestically in a bid to become the global center of NHP research.[2] China officially presented the ban as a precautionary measure to prevent potential zoonotic crossover and further spread of Covid-19. However, the lack of a reversal on the ban more than two years later and other documents stating China's intentions for future NHP research suggest that the Chinese authorities seized on a crisis to justify a strategic decision that they intended to take anyway.

This essay provides an overview of the divergence in NHP research between the United States and China as a means for identifying both the different forms of strategic thinking that brought about the divergence and the future implications now that it is taking place. To do so, the essay assumes the merits of NHP research and its continued necessity.[3] The first section briefly discusses China's goal of dominating future biotechnology development as the guiding force behind its prioritization of NHPs as a strategic resource. The essay then explores the current state of the divergence in NHP research between the United States and China and considers trends suggesting that the disparity in research capacity and developments will grow in the future. Next, the essay assesses the implications for the future of pharmaceutical development and the control of broader AI and brain-inspired computing systems. Finally, the conclusion explores possible future outcomes of the divergence in NHP research and what China's control of NHPs could mean for the future of U.S. biotechnology supremacy.

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1 Guoping Feng et al., "Opportunities and Limitations of Genetically Modified Nonhuman Primate Models for Neuroscience Research," *Proceedings of the National Academy of Sciences* 117, no. 39 (2020): 24025.

2 See State Administration of Market Supervision, the Ministry of Agriculture and Rural Affairs, and National Forestry and Grassland Administration of the People's Republic of China (PRC), "Announcement on Prohibiting the Trade of Wild Animals 2020 Announcement 4," January 2020: "In order to strictly prevent the pneumonia epidemic caused by the new coronavirus infection and block the possible sources of infection and transmission routes, the General Administration of Market Supervision, the Ministry of Agriculture and Rural Affairs, and the State Forestry and Grassland Administration have decided to prohibit trading activity involving wild animals from the date of this announcement until the nationwide epidemic is lifted."

3 For a thorough analysis of the merits of NHP research, which is beyond the scope of this essay, see Rowan Pierson, "Divergence in Non-Human Primate Research between the United States and China" (BA thesis, Princeton University, 2022), 11–41, http://arks.princeton.edu/ark:/88435/dsp01z316q480r.

Challenging U.S. Biotechnology Supremacy

China aspires to become the global leader in the development and application of future strategic technologies, including pharmaceuticals, AI, and biotechnology. The control of future biotechnology development and U.S. supremacy in this field are at stake.[4] Having established substantial industrial capacity, China is now moving forward with a plan to become an innovator rather than solely a producer—from "made in China" to "discovered in China"—within the next decade.[5] To this end, the country has clearly stated its intentions of dominating the biotechnology and global pharmaceutical industries in state documents such as "Made in China 2025" and the most recent five-year plan of the Chinese Communist Party (CCP). For example, Article IV of the 14th Five-Year Plan asserts China's goal of becoming a science and technology (S&T) "powerhouse" that is self-reliant in development and that controls key and core technologies at the global level.[6] The core technologies and scientific fields emphasized by the CCP include new-generation AI, brain science and brain-inspired research, genetics and biotechnology, and clinical medicine and health (e.g., research into pathogenesis, treatment, and prevention of disease).

The prioritization of NHPs as a strategic resource reflects the CCP's goal of dominating future biotechnology developments. Given their value for verifying the efficacy of new pharmaceuticals and therapeutics, developing integrated brain-computer systems, and studying the basis of cognition and intelligence, the CCP views control of NHPs as key to achieving its S&T development goals. As such, the ban on NHP exports in response to the Covid-19 pandemic fits into its long-term Made in China 2025 strategy of conducting primate research and consolidating the rewards of such research in China.[7] There is evidence as far back as 2007 of China working toward this goal, with calls from Chinese primate researchers for the government to designate the rhesus macaque a "national strategic resource" and to ban exports of the animal.[8] The likelihood that the country plans to use its NHP resources as a chokepoint for biotechnology development seems even more certain given a report that the CCP plans to restrict the sale of Chinese NHPs to companies or research institutions with Chinese ownership or some form of Chinese investment.[9] Accordingly, China seems to be moving toward the goal of becoming the country where all therapeutic strategies must be validated.[10]

Another Chinese program focused on NHP research is the China Brain Project. The project was initiated around the same time as the 13th Five-Year Plan and is a fifteen-year (2016–30) initiative focused on both basic and applied neuroscientific research to compete with similar projects in the United States and Europe.[11] Unlike the brain projects in the West, however, the China Brain

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4 Anna Puglisi, testimony before the U.S. Senate Select Committee on Intelligence, Washington, D.C., August 4, 2021, https://cset.georgetown.edu/publication/anna-puglisis-testimony-before-the-senate-select-committee-on-intelligence.

5 Rosemary Gibson, *China Rx: Exposing the Risks of America's Dependence on China for Medicine* (Amherst: Prometheus, 2018), 92.

6 National People's Congress, *Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035* (Beijing, March 2021), trans. Etcetera Language Group, March 12, 2021, 11, available at https://cset.georgetown.edu/publication/china-14th-five-year-plan.

7 "Attitudes towards Experimenting on Monkeys Are Diverging," *Economist*, July 24, 2021, https://www.economist.com/international/2021/07/24/attitudes-towards-experimenting-on-monkeys-are-diverging. Prior to the 2020 export ban, China supplied between 20,000 and 25,000 (60% and 70%) of the roughly 34,000 NHPs imported into the United States annually (mostly cynomolgus macaques, the animal favored by pharmaceutical companies for research studies and safety testing). See Sui-Lee Wee, "Future Vaccines Depend on Test Subjects in Short Supply: Monkeys," *New York Times*, February 23, 2021, https://www.nytimes.com/2021/02/23/business/covid-vaccine-monkeys.html.

8 Xin Hao, "Monkey Research in China: Developing a Natural Resource," *Cell* 129 (2007): 1033.

9 Author's virtual discussion with Erwan Bezard, January 17, 2022.

10 David Cyranoski, "Monkey Kingdom," *Nature* 532 (2016): 301; and author's virtual discussion with Bezard.

11 Mu-ming Poo et al., "China Brain Project: Basic Neuroscience, Brain Diseases, and Brain-Inspired Computing," *Neuron* 92 (2016): 595.

Project emphasizes the importance of NHP research, citing the essential role of developing a "mesoscopic circuit analysis of the macaque brain" for understanding the origin and organization of human cognition.[12] The project also focuses on the development of brain-integrated computing and brain-computer interface (BCI) technologies, which rely on access to NHPs for validation and safety testing before they can be used in humans. While China has publicly expressed a desire to collaborate with researchers in the United States and Europe on NHP neuroscience research, it is clear that foreign researchers will have to travel to China to work with these primate resources.[13]

Furthermore, China recognizes the decline of NHP research in the United States and Europe and, consequently, the opportunity not only to control NHP resources but to take on the responsibility of training the next generation of primate neurobiologists.[14] Through the China Brain Project and other primate research initiatives, China is setting itself up to become the global vanguard of NHP research. Thus, it could soon become the country not only where the vast majority of such research is conducted but also where students and scientists interested in working with NHPs must go to study.

U.S.-China Divergence in NHP Research

Both the United States and China are actively engaged in significant NHP research. They lead the world not only in the amount of research conducted but also in the application of their results to develop new therapeutics and understanding of the human body and disease. The three areas in which China and the United States diverge in their approaches to and implementation of NHP research are (1) public attitudes toward NHP research and government investment in such research, (2) the number of research animals used and available for use and the cost of conducting such research, and (3) the laws, regulations, and research ethics governing NHP research. A summary of each area of divergence is provided in **Table 1**.

Attitudes and Government Investment

The United States and China differ significantly with respect to public attitudes and government investment in NHP research. Animal rights groups in the United States have been increasingly applying pressure, sometimes violently, on scientists and government leaders to end animal experimentation more generally, with particular emphasis on ending NHP research.[15] Animal rights activists are not alone in their views. A poll conducted by the Pew Research Center in 2018 found that roughly 52% of Americans opposed the use of animals in scientific research.[16] The lack of public understanding, in conjunction with the lobbying of animal rights activists, is having an effect on policymakers. A 2020 U.S. spending bill required "the National Institutes of Health (NIH) to explore alternatives to the use of nonhuman primates, the Food and Drug Administration (FDA) to come up with a detailed plan for the reduction and retirement of its

12 Poo et al., "China Brain Project," 592.

13 Dennis Normile, "China Bets Big on Brain Research with Massive Cash Infusion and Openness to Monkey Studies," *Science*, September 20, 2022, https://www.science.org/content/article/china-bets-big-brain-research-massive-cash-infusion-and-openness-monkey-studies.

14 Poo et al., "China Brain Project," 594.

15 "Attitudes towards Experimenting on Monkeys Are Diverging."

16 Mark Strauss, "Americans Are Divided over Use of Animals in Scientific Research," Pew Research Center, August 16, 2018, https://www.pewresearch.org/fact-tank/2018/08/16/americans-are-divided-over-the-use-of-animals-in-scientific-research.

TABLE 1 Summary of the three areas of divergence

Areas of divergence	United States	China
Attitudes and government investment	Government support and investment for NHP research is lacking; substantial negative public attitudes toward primate biomedical research exist; animal rights activism is significant.	New investment in and government prioritization of NHP research is substantial; no public opposition to animal research exists; there is virtually no organized animal rights activism.
Numbers	Thousands of NHPs are used in research annually, but there is a substantial shortage of primates needed for future research and insufficient infrastructure and breeding capacity to address the shortage; the cost of NHP research is much higher than in China.	Prior to 2020, China exported roughly 20,000 NHPs to the United States annually; China is now focusing on using its NHP resources domestically, increasing the number of NHPs used in research by 10,000 annually since 2018, when the number used was 8,000; the cost of NHP research is much cheaper.
Laws, regulations, and research ethics	NHP research is tightly regulated, and existing laws ensure that strict animal welfare standards and procedures are followed; there is a strong culture of animal welfare and animal research ethics among researchers and research institutions.	Regulation of animal research is in its infancy; although existing laws and standards in many ways match those of the United States, enforcement is absent; there is no strong culture of animal welfare standards in research; many researchers educated in China lack sophisticated knowledge of animal welfare practices.

monkeys, and the Department of Veterans Affairs (VA) to reduce or eliminate its use of cats, dogs, and monkeys within the next 5 years."[17] Likewise, the lack of public and government support for NHP research has led to over two decades of underfunding for the seven national primate research centers, which conduct invaluable research on human diseases, disorders, and biological processes (such as those affecting cognition).[18] The centers have been underfunded for so long that it would require an estimated one-time investment of around $50 million to reset and revamp them and possibly hundreds of millions of dollars more to restore their leadership position.[19]

In contrast to the United States, China has identified NHPs as a strategic resource and is actively investing in primate research. The Chinese government believes that NHPs hold the key to future advancements in neuroscience and pharmaceutical development for a range of diseases and disorders. Unlike in the United States and Europe, there is virtually no animal rights activism in China, and only recently have animal welfare standards been widely implemented in the country.[20]

[17] David Grimm, "2020 U.S. Spending Bill Restricts Some Animal Research, Pushes for Lab Animal Retirement," *Science*, December 19, 2019, https://www.science.org/content/article/2020-us-spending-bill-restricts-some-animal-research-pushes-lab-animal-retirement.

[18] Author's virtual discussion with Deepak Kaushal, January 27, 2022.

[19] Ibid.; and Nidhi Subbaraman, "The U.S. Is Boosting Funding for Research Monkeys in the Wake of COVID," *Nature* 595, no. 7869 (2021): 634.

[20] Deborah Cao, *Animals in China: Law and Society* (Houndmills: Palgrave Macmillan, 2015), 149.

In China, both under the law and in public attitudes, "improving human health comes first."[21] In one study of attitudes toward animal research, respondents from China were more likely to be accepting of animal research, particularly with primates, than respondents from Japan and the Netherlands (a proxy for attitudes in the United States).[22] The authors traced this difference to the fact that Chinese people "attach greater importance to medical progress and are more likely to accept animal-based medical research owing to its contribution toward scientific progress," as well as to China's status as a country where public awareness and oversight of animal research are still in their infancy.[23]

Similarly, scientific development is seen as a public good and a key driver of China's geopolitical and economic ascension. As such, the country has been far more willing than the United States to invest in NHP resource development in recent years. Since the mid-2000s, China has been increasing investment in its primate research infrastructure, with over one hundred institutions currently providing primate models or conducting primate research.[24] The largest primate facility, the National Resource Center for Non-human Primates, which is part of the larger Kunming Institute of Zoology operated by the Chinese Academy of Sciences, has been under construction for the past decade. It began to solicit research proposals from domestic and international researchers in spring 2022, signaling its imminent completion.[25] China's continued investment in such a long-term project with the ambition of becoming a global center for NHP research demonstrates its commitment to the development of its NHP resources moving forward.

Numbers

The divergence between the United States and China is also reflected in differing trends in the number of NHPs available for research. U.S. Department of Agriculture data shows that the number of NHPs used and housed in research facilities in the United States annually has remained relatively constant over the last decade, at roughly 110,000 NHPs.[26] In contrast, the cost of conducting NHP research has fluctuated substantially, especially as a result of the spike in demand for primate models and China's NHP export ban during the Covid-19 pandemic. In the United States, the cost of an individual monkey prior to the pandemic was roughly $6,000, but since then the cost has nearly doubled to more than $10,000. According to some reports, desperate research firms are willing to pay as much as $30,000 for a single animal.[27]

The situation in China is far different. Although data on the number of research animals used is not publicly available, there are at least 24 primate species endemic to the country, including

21 Quoted in Hao, "Monkey Research in China," 1035. The same sentiment has been expressed in other news and research articles, including by the assistant to the chair of one of China's primate research facilities. See, for example, Sarah Zhang, "China Is Genetically Engineering Monkeys with Brain Disorders," *Atlantic*, June 8, 2018, https://www.theatlantic.com/science/archive/2018/06/china-is-genetically-engineering-monkeys-with-brain-disorders/561866.

22 Bingtao Su, Chao Zhang, and Pim Martens, "Attitudes in China, Japan, and the Netherlands toward the Use of Animals in Medical Research," *Anthrozoös*, November 23, 2021, 5.

23 Ibid., 9.

24 Lucille Nalbach Tournas and Nicholas Shadid, "China's Unexpected Advantage in the Global Competition over Brain-Computer Interfaces," Slate, November 23, 2022, https://slate.com/technology/2021/11/china-brain-computer-interface-research-nonhuman-primates.html.

25 Yong-Gang Yao, "Towards the Peak: The 10-Year Journey of the National Research Facility for Phenotypic and Genetic Analysis of Model Animals (Primate Facility) and a Call for International Collaboration in Non-human Primate Research," *Zoological Research* 43, no. 2 (2022).

26 U.S. Department of Agriculture, "Research Facility Annual Summary and Archive Reports," USDA Animal and Plant Health Inspection Service, March 2, 2022.

27 Steve Boggan, "China's Plan for Medical Domination," UnHerd, February 8, 2021, https://unherd.com/2021/02/chinas-plan-for-medical-domination; and Cyranoski, "Monkey Kingdom," 301.

the rhesus macaque, which is the preferred species for many research disciplines.[28] In addition, China has a robust network of facilities that specialize in breeding cynomolgus macaques (the species preferred by the pharmaceutical industry) and rhesus macaques, largely for export to institutions in the United States and Europe prior to 2020. In 2013, for example, the China Laboratory Primates Breeding and Development Association reported that there were 250,000 breeding cynomolgus macaques and 40,000 breeding rhesus macaques in the country's primate facilities, with approximately 50,000 to 60,000 more animals born annually.[29] These numbers remain constant today. It is estimated that more than 240,000 experimental NHPs were housed in China in 2022, over double the number available in the United States.[30] Of these animals, the stock of primates available for commercial use is around 100,000, with 30,000 slated for domestic use in 2019, an increase of 20,000 from only two years prior.[31] Furthermore, although NHP research was previously far cheaper to conduct in China than in the United States, with an individual monkey costing only around $1,000 in 2016 and $2,000 in 2019, China's NHP research industry was also affected by excess demand during the pandemic, with the cost of monkeys jumping to around $9,600.[32] The cost will likely come down, however, as China continues its policy of banning NHP exports and increases the utilization of its domestic supply to match demand.

Laws, Regulations, and Research Ethics

A final difference between the United States and China is the content, implementation, and enforcement of laws, regulations, and ethics regarding animal research. In the United States, laboratory animal research is strictly regulated by national and state laws, federal standards, institutional guidelines, and animal research ethics that conform to the widely established 3Rs paradigm (replacement, reduction, and refinement).[33] Not only is NHP research highly regulated, but there is also strict enforcement. The U.S. Department of Agriculture is empowered to inspect research facilities whenever it chooses and to "impose sanctions, levy fines, suspend activities, or close down operations" if violations are identified.[34] The statutory protections and enforcement of NHP research standards are further bolstered by widely established animal research ethics, including the belief that using animals in research is a privilege and the expectation that such research will only be conducted when it can either provide significant new knowledge or lead to improvements in human or animal well-being.[35]

In contrast, China's regulation of animal research and understanding of animal welfare ethics are far weaker. Only 30 years ago, there was essentially no concept of laboratory animal science

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28 Xiao-Liang Zhang et al., "Experimental Primates and Non-Human Primate (NHP) Models of Human Diseases in China: Current Status and Progress," *Zoological Research* 35, no. 6 (2014): 450.

29 Ibid., 450.

30 "Experimental Monkeys Become Hot Commodity in China Despite Soaring Prices as Domestic Innovative Drug R&D Projects Grow," *Global Times*, June 13, 2022, https://www.globaltimes.cn/page/202206/1268008.shtml.

31 Wang Bozun and Liu Zhongyin, "Lack of Experimental Monkeys Unlikely to Affect Development of Covid-19 Vaccine: Experts," *Global Times*, April 21, 2021, https://www.globaltimes.cn/page/202104/1221678.shtml.

32 "NYT Ridiculed for Double Standard against China for Shortage of Lab Monkeys and the Ban on Wildlife Sale," *Global Times*, February 25, 2021, https://www.globaltimes.cn/page/202102/1216492.shtml.

33 The 3Rs paradigm is an approach to animal welfare designed to limit harm to animals used in laboratory research by (1) replacing lab animals with alternative methods or lower-order species, (2) reducing the number of animals used in studies, and (3) refining lab practices to minimize overall harm to animals and develop new approaches that lead to replacement and reduction.

34 Author's virtual discussion with John P. Capitanio, February 2, 2022; and Lesley A. Sharp, *Animal Ethos: The Morality of Human-Animal Encounters in Experimental Lab Science* (Oakland: University of California Press, 2019), 46.

35 National Research Council, *Guide for the Care and Use of Laboratory Animals*, 8th ed. (Washington, D.C.: National Academies Press, 2011), 4.

in China.[36] As a result, it gained a reputation for being the "wild west" of animal research, with little oversight or concern for animal research ethics and a willingness to pursue experiments that are not permitted in countries like the United States. While regulations and enforcement are still far weaker and less specific than in the West, China's reputation as a location for "ethics dumping" is no longer accurate.[37] Over the past several decades, the country has passed laws and national guidelines establishing standards for laboratory facilities, animal care, and animal welfare. In addition, the return to China of researchers studying or working at U.S. and European institutions has increased the adoption of regulations and practices similar to those used in the West.[38] Furthermore, China's desire to become the global leader in pharmaceutical development and production has engendered the rapid improvement of regulations and oversight, as regulatory agencies like the FDA and European Medicines Agency require foreign companies to meet U.S. and European animal welfare standards in their R&D.[39]

Nonetheless, although Chinese standards may be closely aligned with Western regulations in terms of the language used, there is little information about whether or how strictly the guidelines are enforced in China, and the penalties for violations are vague and not well understood by Chinese researchers. Significantly, there have been no publicly documented cases of enforcement or sanctions against researchers for violations.[40] Some reports from researchers in China indicate that breaches of euthanasia protocols and other unethical experimental practices are commonplace and that illegal or unregistered animal research still takes place in many locations.[41] The enforcement of research regulations is, therefore, a final difference between China and the United States.

Implications of the Divergence

The implications of the divergence in NHP research between the United States and China are significant. Moving forward, control of NHP research is likely to have broad consequences for access to new therapeutics, where the validation of pharmaceuticals takes place, as well as for the development of emerging technologies of strategic interest (e.g., new pharmaceuticals, gene-editing tools and other biotechnologies, and advanced AI and brain-inspired computing systems). This section explores these implications and the possible consequences of the divergence in NHP research for the future control of strategic technologies.

The Future of Pharmaceutical Development

China's actions to cultivate and enhance NHP resources are designed to secure the future advantage of its biotechnology industry and to ensure Chinese control of research innovations

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36 National Research Council, *International Animal Research Regulations: Impact on Neuroscience Research* (Washington, D.C.: National Academies Press, 2012), 13.

37 "Ethics dumping" is defined here as "taking either active or passive advantage of loopholes and weaknesses in governance systems of another country in order to perform research that would be legally or ethically unacceptable in their own country." See Louiza Kalokairinou and Isidoros Karatzas, "Foreword," in E*thics Dumping: Case Studies from North-South Research Collaborations*, ed. Doris Schroeder et al. (Cham: Springer International, 2018), vii.

38 National Research Council, *International Animal Research Regulations*, 15.

39 Author's virtual conversation with Paul J. Reider, January 19, 2022.

40 Deborah Cao, "Ethical Questions for Research Ethics: Animal Research in China," *Journal of Animal Ethics* 8, no. 2 (2018): 143.

41 Cao, *Animals in China*, 132.

in the field. By controlling access to more research NHPs than any other country, China can strategically utilize these resources to stall the drug discovery process of U.S. companies by refusing to export NHPs outside China, encourage U.S. companies to conduct their safety and efficacy animal testing in China by offering to provide access to NHPs domestically, and give Chinese companies and researchers a competitive advantage by providing nearly limitless resources and a research-friendly ethical and regulatory environment.[42] For example, as a result of looser ethical regulations, China is willing to invest in gene-editing experiments in NHPs that are not being pursued in other countries, with the goal of translating the results to humans.

China's decision to leverage NHPs as a potential chokepoint for U.S. pharmaceutical development and an incentive for foreign companies to conduct their NHP work in China fits into the CCP's broader technology transfer initiatives. If foreign companies are incentivized or even forced to conduct their NHP experiments in China, they will necessarily be exporting their own technology and expertise.[43] Additionally, Chinese researchers and companies will likely be able to view data from experiments conducted in China, giving them the double advantage of access to both their own data and the data generated by foreign companies.[44] Even NHP research initiatives that are presented as opportunities for collaboration between U.S. and Chinese researchers and institutions risk advantaging the Chinese pharmaceutical industry at the expense of U.S. companies, due to the asymmetric transfer of knowledge that occurs during research and investment partnerships with China. As evidenced by current and past joint scientific endeavors, "it is naive at best to believe that developments made by China will be shared equally, without restrictions or strings attached, because it is what is best for humankind."[45]

China has already begun to leverage its NHP resource advantage to bolster its own pharmaceutical industry while disadvantaging foreign companies and research institutions. Contrary to the claim by Chinese officials that their decision to ban the export of research primates was a health measure in response to the Covid-19 pandemic, the export ban is a clear example of a chokepoint designed to advantage China's own pharmaceutical and biotechnology industries. Consequently, exports of NHPs from China are unlikely to return to previous levels, leaving many U.S. researchers and pharmaceutical companies that previously relied on Chinese exports in a difficult position. Although other countries, such as Cambodia, have stepped in to fill the gap, there are substantial questions about both the quality of those animals and the sustainability of the colonies maintained by these alternative breeders and suppliers.[46] The lack of access to high-quality research primates outside China is, therefore, likely to hasten the trend of multinational pharmaceutical companies in the United States outsourcing safety and efficacy testing for NHP research to facilities or affiliates in China.[47]

Additionally, the ethical and oversight asymmetry between NHP research in the United States and China is already having broad consequences for the development of new biotechnologies such as gene editing. China is openly and actively attempting to engineer colonies of genetically altered primates using CRISPR technology to create models of human diseases such as diabetes, autism,

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42 Tournas and Shadid, "China's Unexpected Advantage."

43 Ibid.

44 Puglisi, testimony before the U.S. Senate Select Committee on Intelligence.

45 Ibid.

46 David Grimm. "Indictment of Monkey Importers Could Disrupt U.S. Drug and Vaccine Research," *Science*, November 23, 2022, https://www.science.org/content/article/indictment-monkey-importers-could-disrupt-u-s-drug-and-vaccine-research.

47 Author's virtual conversation with Reider.

Alzheimer's, and tuberculosis, among many others.[48] There is some skepticism that Chinese researchers will be able to create accurate models of complex diseases such as Alzheimer's in the near future.[49] If, however, the venture is successful, or if the models created are the best available, then China will have a substantial advantage in developing treatments for such diseases. Although similar work is being done in the United States, no work is currently being undertaken at the national primate research centers to create specific disease models using gene editing.[50] As a result, China has a first-mover advantage in developing disease models and conducting work in NHPs to further refine CRISPR technology that could eventually be used therapeutically in humans. The large number of monkeys at NHP research and breeding facilities in China makes them "the ideal proving ground for new genetic-engineering technologies."[51]

Furthermore, China has created an integrated system for translating primate experiments into human clinical trials through cost and speed incentives, giving the country an additional advantage in refining and applying gene-editing technologies that hold the key to future therapeutic interventions.[52] If new gene-editing therapies are first developed in China, the United States and other countries will be forced to play catch-up and will need to either rely on China for access to the technology or wait for the lag in development of their own domestic alternatives.

AI and Brain-Inspired Computing

The importance of NHP research in developing a greater understanding of the human brain and the origins of human cognition and intelligence cannot be overstated. Less emphasized, however, is the role that it can play in the pursuit of AI and newly developed brain-inspired computing and BCI technologies. The following quote nicely captures the implications of using such research to develop AI and how China can take advantage of NHPs to win the global race to develop broader and more integrated AI systems:

> Probing the workings of the brain is a 21st-century equivalent to exploring the farthest reaches of the planet. The results will not only teach humans about their own minds but will also help them design artificial intelligence—a separate but connected field in which competition between countries has become fierce. If such scientific knowledge is largely produced in China and Japan, it will become ever harder for others to catch up, should they decide they wish to do so.[53]

Currently, China recognizes the potential of NHPs in this field and is actively conducting research targeted at AI development, while the United States is without an articulated strategy to utilize its own NHP resources in the pursuit of new AI technology.

There is no certainty about how general AI or broad AI (used interchangeably in this essay) will be achieved, or about what exactly "it" is, because "there are no precedents, no metrics to measure progress, and no clear break between AI and what meets (someone's) threshold for 'advanced'

48 CRISPR is an acronym for clustered regularly interspaced short palindromic repeats, a family of DNA sequences.

49 Author's virtual conversation with Sabine Kastner, February 7, 2022.

50 Skip Bohm, email message to author, February 2, 2022.

51 Zhang, "China Is Genetically Engineering Monkeys."

52 Tournas and Shadid, "China's Unexpected Advantage."

53 "Attitudes towards Experimenting on Monkeys Are Diverging."

AI."[54] China and the United States are pursuing three potential avenues that could ultimately lead to the development of a broader AI system. One avenue is brain-inspired AI. It seeks to replicate in a computer naturally occurring biological processes in human or primate brains, such as higher cognitive skills, without necessarily copying the exact biological mechanism or, conversely, by writing mathematical models that directly and accurately describe the biological processes taking place to reproduce the observed intelligent behavior.[55] Given the extensive data available on NHP behavior and the continued development of our understanding of primate brains, NHPs are likely to play an important role as a bridge to eventual brain-inspired AI modeled on the human brain.

A second avenue is connectomics, also known as "brain mapping." While pursuing the same goal as brain-inspired AI, it is conceptually different and refers to "empirical and computational efforts to replicate on multiple levels the structure, function, and system features of neurobiological circuitry," especially the mammalian central nervous system.[56] NHPs are expected to play a substantial role in the development of connectomics, and the China Brain Project is currently developing a mesoscopic model of the macaque brain as the next step toward a full model of the human brain.

Last, BCIs integrate real and artificial intelligence through devices that acquire electrical signals from live brains, "analyze them on computers and, optionally, translate the signals into actionable commands."[57] As with brain-inspired AI and connectomics, NHPs will be utilized extensively in the pursuit of more advanced BCI. They have already been used to develop therapeutic implants such as deep brain stimulation to treat Parkinson's disease and can serve as models to test both the functionality and safety of BCI systems prior to their use in humans.

From a policy perspective, China is fully committed to becoming the first country to realize the goal of developing advanced AI. In 2017 the State Council issued a groundbreaking document entitled "A Next Generation Artificial Intelligence Development Plan,"[58] which outlined a top-level approach to achieving advanced AI with broad goals established through 2030. The plan was closely connected to the announcement of the China Brain Project in 2016. China views the advancement of neuroscience and the understanding of human cognition as parallel to the goals of developing broader and more capable AI, which explains its focus on the pathways of brain-inspired AI, connectomics, and BCIs. The China Brain Project explicitly makes this connection. Its "one body, two wings" design is intended to leverage understanding of the neural basis of cognitive function (body) to develop "brain-machine intelligence technologies" (wing one) and "effective approaches in early diagnosis/intervention of brain disorders" (wing two).[59]

China not only enjoys the advantage of government policy designed to maximize its odds of achieving general AI but also holds several other natural advantages over the United States. One key advantage, as discussed earlier, is that the country is home to "the world's largest supply of

54 In the context of this essay, general and broad AI both describe a machine with broad learning and decision-making capacity, "which may be comparable (by some measure) to human-level intelligence, or less capable, or exceed it in some or all domains." See William C. Hannas et al., "China's Advanced AI Research: Monitoring China's Path to 'General' Artificial Intelligence," Georgetown University, Center for Security and Emerging Technology, July 2022, 3, 5.

55 William C. Hannas et al., "China AI-Brain Research," Georgetown University, Center for Security and Emerging Technology, September 2020.

56 Ibid., 2.

57 Ibid.

58 "In Their Own Words: A Next Generation Artificial Intelligence Development Plan," China Aerospace Studies Institute, trans. DigiChina Project, July 20, 2017, 2, https://www.airuniversity.af.edu/Portals/10/CASI/documents/Translations/2021-03-02%20China's%20New%20Generation%20Artificial%20Intelligence%20Development%20Plan-%202017.pdf?ver=N2TtRVNODYyWR0yGHuK_cA%3d%3d.

59 Poo et al., "China Brain Project," 592.

non-human primates bred for research, and an ethical framework conducive to experimentation."[60] The stagnation and funding decline in NHP research in the West, in parallel with China's substantial investment in NHP neuroscience research, gives the country a potentially significant advantage in the pursuit of general AI. China has the facilities and the NHP resources to carry out experiments that are currently impossible in the United States and Europe.[61] Furthermore, China has become the global center for research involving macaques, widely considered the best available NHP model for research on the human brain, and studies are already being undertaken in macaques with the aim of developing advanced AI and BCI systems.[62] The China Institute of Military Cognition and Brain Science has engaged in research on BCI technology through electroencephalograms via the scalp and implants in the cranial nerves of macaques.[63] Likewise, Chinese scientists have conducted the first studies of their kind to "experimentally interrogate the genetic basis of human brain origin using transgenic monkey models" through the introduction in macaques of human genes thought to influence memory and intelligence capabilities.[64]

These examples demonstrate the ways that China is currently moving forward with AI research using NHPs, exploiting its superior resources and advantages to explore avenues that are unavailable or not being pursued in the United States. Although Chinese researchers acknowledge that they still lag behind the United States in the race to develop BCI systems, they claim that they can catch up in the next five to ten years.[65] This view may be overly optimistic, but given China's advantage in NHP resources, the lower cost, the faster speed, and the environmental incentives (i.e., looser ethical frameworks and regulatory oversight) that the CCP is employing to reach its BCI and advanced AI development goals, it is possible that China could soon overtake the United States in this field.

China's dominance of NHP research in connection with its AI-brain program presents potential long-term challenges for U.S. and world security. Chinese military leaders believe that AI will inevitably be weaponized and that once AI and BCI systems are sufficiently developed, they will transform future warfare.[66] AI will ultimately transform battlefield and human capabilities, especially through new forms of BCI that are used to enhance human knowledge capabilities and decision-making power. For example, Lieutenant General Liu Guozhi, director of China's Central Military Science and Technology Commission, stated that "the combination of artificial intelligence and human intelligence can achieve the optimum, and human-machine hybrid will be the highest form of future intelligence."[67] The utilization of NHPs to develop new forms of BCI, therefore, can be understood as the pursuit of a technology that will ultimately be weaponized. Moreover, if human-machine hybrid intelligence does become the highest form of intelligence, the question becomes whether the United States ultimately trusts China's control and development of such technology. Likewise, there is a potential security risk in widely utilizing Chinese-made BCI technology, given concerns about the Chinese government's violations of privacy and the current lack of quality assurance for Chinese-made products, including pharmaceuticals.

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60 Hannas et al., "China AI-Brain Research," 62.

61 Elsa B. Kania, "Minds at War: China's Pursuit of Military Advantage through Cognitive Science and Biotechnology," *Prism: A Journal of the Center for Complex Operations* 8, no. 3 (2020): 90.

62 Ibid., 90.

63 Ibid., 88.

64 Ibid., 90.

65 Tournas and Shadid, "China's Unexpected Advantage."

66 Kania, "Minds at War," 83.

67 Ibid.,84.

While by no means the only factor that will influence the control of future AI technology, given the importance of NHPs in studying cognition and developing BCI systems, control of NHP resources may be key to determining which country arrives at advanced AI first. In particular, the ability to test and refine BCI technology in NHPs before applying it in humans could be a key step on the pathway toward realizing advanced BCI systems that lead to the sort of intelligence advancement and weaponization described by Lieutenant General Liu. Likewise, the realization of a full connectome of the macaque brain (a key goal of the China Brain Project) will likely enhance understanding of brain design and primate cognition and thereby accelerate China's development of advanced brain-inspired AI.

Even if the United States continues to fund and pursue NHP research in its current capacity, China's superior NHP resources and greater focus on applications targeted at emerging technologies like AI will allow it to pursue NHP-AI research in a way that the United States cannot match. As such, the divergence in NHP research between the two countries and the lack of emphasis on NHP-AI research in the United States could have significant consequences for which country first arrives at broad AI.

Future Scenarios

There is a nearly universal consensus among scientists that NHPs continue to be irreplaceable in drug development, neuroscience, and other biotechnology research fields. A recent panel of experts underscored the ongoing need to rely on NHPs, as some data is impossible to gather at this time using artificial systems or smaller animal models (e.g., mice).[68] Additionally, while other countries have large populations of NHPs that could be used in research, China remains the leader not only in access to high-quality research NHPs but also as the only place where it is possible to work with large populations of genetically modified animals.[69] Other primate-export countries face issues with supply sustainability and animal quality, and some have even imposed their own bans on the export of research primates.[70] As such, the ascendancy of China's primate research program in tandem with the decline of primate research capacity in the United States may pose substantial challenges moving forward.

Consequently, the future impact of the divergence in NHP research between the United States and China hinges on the continued utility of primate research and how quickly alternative technologies are developed. There is a possibility that developments in alternative technologies over the next decade will allow for the replacement of NHPs in most fields currently relying on such research. While these technologies are not sufficiently developed at present, some scientists have argued that NHPs can already be replaced in many scenarios.[71] Furthermore, although NHPs remain a vital tool in drug discovery and neuroscience research, they are likely to play a less significant role in the development of advanced AI and BCI systems. Accordingly, it is not certain

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68 National Academies of Sciences, Engineering, and Medicine, "State of the Science and Future Needs for Nonhuman Primate Model Systems—Meeting 6," webcast, November 21, 2022, https://www.nationalacademies.org/event/12-01-2022/state-of-the-science-and-future-needs-for-nonhuman-primate-model-systems-meeting-6#sectionEventMaterials.

69 Grimm, "Indictment of Monkey Importers"; and author's virtual discussion with John Morrison, January 28, 2022.

70 Author's virtual discussion with Morrison; Grimm, "Indictment of Monkey Importers"; and "NYT Ridiculed for Double Standard."

71 Jarrod Bailey and Katy Taylor, "Non-human Primates in Neuroscience Research: The Case Against Its Scientific Necessity," *Cruelty Free International* 44 (2016): 63; and Jarrod Bailey, "Monkey-Based Research on Human Disease: The Implications of Genetic Differences," *Alternatives to Laboratory Animals* 42, no. 5 (2014): 288.

that China's NHP research advantage will be the key to winning the AI development race (although it is important to note that any advantage in the race could prove crucial). Finally, through the refinement of NHP research techniques and the development of new tools and methods, it is possible that the United States could still compete in this field using its comparatively inferior resources. The sheer size of China's NHP resources and its friendlier research environment do not necessarily correlate to a disparity in research achievements.

However, in a scenario where primates continue to be an irreplaceable model over the next decade or more, the divergence in NHP research presents a significant challenge to U.S. supremacy in biotechnology development. Although the United States still retains substantial primate resources of its own at private institutions and its national primate research centers, the shortage in resources is only likely to grow. Without substantial investment on a scale not seen previously, the United States cannot compete by increasing its own breeding capacity.[72] Accordingly, U.S. researchers and companies will increasingly move their work to China or travel there for short-term research projects, increasing the likelihood of asymmetric technology transfer and further enhancing China's advantages in the NHP research field. There is also a danger that China will continue to use its superior NHP resources as leverage to create one-sided partnerships that disadvantage the U.S. biotechnology industry while advantaging China's domestic corporations. Moreover, China's looser regulatory environment and greater willingness to push the ethical bounds of research into emerging technologies like applied genetic editing using NHPs pose a danger that the country will control these technologies prior to the establishment of global regulatory and ethical frameworks, potentially forcing the U.S. population to rely on Chinese technology that is inherently vulnerable to data privacy breaches.

Additionally, there is a danger in relying on China for access to NHP resources during a future health crisis that requires the efficient testing of new therapies. As the Covid-19 pandemic demonstrated, access to NHPs is critical to the rapid development and deployment of safe and effective vaccines. NHP research, for example, was crucial in demonstrating the effectiveness of the newly utilized mRNA vaccines that have proved extremely potent in combating Covid-19.[73] If China dominates global NHP research in the next decade, the United States and Europe could depend on the goodwill of its autocratic government to ensure that their companies can validate new therapeutics using NHPs and that any successful developments made in China are shared in a timely manner. Moreover, given China's lack of a proven track record in pharmaceutical development and lack of transparency around Covid-19, relying on the country in such a scenario could be damaging for both global health and U.S. security.

Regardless of whether a high- or low-utility NHP research scenario begins to take shape over the next decade or two, the world is yet to live in a post–Industrial Revolution era where the United States is not the leader in emerging technology development. As such, any advantage that will allow China to overtake the United States in biotechnology development requires substantial consideration. Although the United States cannot match China in future NHP research investment or capacity, this does not mean that falling behind in the application of such research is inevitable. Investment in alternative methodologies and creative solutions to limit China's advantage in NHP research could hold the key to helping the United States maintain its global science and technology supremacy.

72 Author's virtual discussion with Kaushal.

73 Ibid.

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Chinese Military Thinking at the Crossroads of Biological Security, Biotechnology, and Global Health

Alexis Dale-Huang and Nathan Beauchamp-Mustafaga

ALEXIS DALE-HUANG is a PhD student in Princeton University's School of Public and International Affairs. She can be reached at <ad1636@princeton.edu>.

NATHAN BEAUCHAMP-MUSTAFAGA is a Senior Policy Researcher at the RAND Corporation. He can be reached at <nathan_beauchamp-mustafaga@rand.org>.

EXECUTIVE SUMMARY

This essay examines People's Liberation Army (PLA) thinking and activities at the intersection of biological security, biotechnology, and global health to better understand how these issues fit in China's evolving military strategy.

MAIN ARGUMENT

PLA sources view the biological domain as an increasingly important consideration for China's national security objectives. With China's enhanced military capabilities and growing desire for great-power status, the PLA will likely emphasize biotechnology and health diplomacy in its future military strategy. These PLA activities are also likely to support the Chinese Communist Party's broader efforts to become a more engaged actor in global health.

POLICY IMPLICATIONS

- The U.S. should encourage greater collaboration between its national security and biotechnology communities that would allow them to exchange findings, share resources, and better understand the context behind the PLA's goals for biotechnology.
- The U.S. should enhance cooperation with its allies to monitor developments and increase awareness of PLA activities at the intersection of military strategy, global health, and biotechnology.
- The U.S. should consider increased interactions between the U.S. Department of Defense and the PLA to discuss global health issues.
- The U.S. should encourage future research on Chinese thinking on biological security and potential Chinese military applications of biotechnology.

With China's expanding military capabilities and growing desire to become a more engaged actor in global health, biotechnology (*shengwu jishu*) and biological security (*shengwu anquan*) have become important considerations for the country's security objectives. Authoritative People's Liberation Army (PLA) texts and articles written by authors affiliated with the PLA have studied the growing importance of biological security and biotechnology. The Chinese Communist Party (CCP) has promoted its military activities and foreign policy initiatives like the Health Silk Road both to address challenges in the biological domain and to position China as a responsible great power in global health. U.S. government officials have become increasingly worried about the potential national security threats posed by biotechnology advancements in China, and concerns are growing about the CCP potentially collecting medical and genetic information.[1]

Although the biological domain is gaining prominence in Chinese strategic thinking, so far there is little foreign understanding of how this area connects with China's broader global health ambitions. This essay will build on the published literature by examining the Chinese military's thinking and activities at the intersection of biological security, biotechnology, and global health to better understand how these issues fit into China's future military strategy. Within this framework, this analysis seeks to answer the following questions: How do Chinese military writings view biological security and China's broader global health ambitions in the context of the country's military strategy? How has the PLA previously been involved in global health initiatives? Could global health initiatives be used to further the Chinese military's development of biological domain capabilities? Finally, how do Chinese global health initiatives support PLA operations and objectives outside of the biological domain?

This essay will also examine PLA activities in these areas that have been carried out since the beginning of the Covid-19 pandemic. This issue is especially of interest to U.S. government officials and analysts as Beijing emphasizes its desire to become a global leader in fields such as biotechnology.[2] So far, research on the PLA's views of biotechnology and how it fits within the Chinese military's biological security ambitions is limited.[3] There is some additional published literature on Chinese global health engagement initiatives more broadly and activities since the beginning of the Covid-19 pandemic.[4] Although Western researchers have paid more attention to developments in Chinese biotechnology research,[5] none of this research has specifically explored the intersection of PLA thinking about biotechnology and global health.

This essay argues that, given China's desire for great-power status, Beijing is very likely to emphasize biotechnology and health diplomacy in its future military strategy, especially following the Covid-19 pandemic. Chinese sources, however, do not suggest that the Covid-19 pandemic was a significant turning point in PLA thinking and behavior. Instead, PLA activities supporting the CCP's foreign policy goal of enhancing China's image as an engaged actor in global health appear to be a continuation of pre-pandemic interest.

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1 Julian E. Barnes, "U.S. Warns of Efforts by China to Collect Genetic Data," *New York Times*, October 22, 2021.

2 Xi Jinping, "Hold High the Great Banner of Socialism with Chinese Characteristics and Strive in Unity to Build a Modern Socialist Country in All Respects," report to the 20th National Congress of the Communist Party of China, October 16, 2022.

3 For examples, see Elsa B. Kania, "Minds at War: China's Pursuit of Military Advantage through Cognitive Science and Biotechnology," *Prism*, no. 3 (2020); Elsa Kania and Wilson VornDick, "China's Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs," Jamestown Foundation, China Brief, 2019; and Larry Wortzel, *Chinese Expectations for Biotechnology and Cognitive Enhancement in Future Warfare* (West Point: Modern War Institute, 2022).

4 Michael W. Wissemann, "Great (Soft) Power Competition: U.S. and Chinese Efforts in Global Health Engagement," *Parameters* 51, no. 3 (2021).

5 Scott Moore, "China's Role in the Global Biotechnology Sector and Implications for U.S. Policy," Brookings Institution, April 2020.

The essay is organized as follows. The first section analyzes select Chinese military sources that discuss biotechnology and biological security. The subsequent section then provides an overview of the PLA's involvement in China's broader global health initiatives. Building on this analysis, the third section speculates on how China's global health ambitions might support or even further shape the PLA's strategy in the future. The essay concludes with considerations for U.S. policy.

PLA Views on the Potential Military Applications of Biotechnology

This section provides an analysis of common themes from PLA writings related to biological security and biotechnology. These themes include PLA views of biological security as an emerging military threat and considerations of future potential military applications for biotechnology. This research is based on a review of statements from high-level Chinese officials, authoritative Chinese military teaching materials, academic research published by Chinese military scholars, and articles from CCP state media outlets. Sources examined include statements by General Secretary Xi Jinping and publications from prominent Chinese military research centers and institutions such as the Academy of Military Science (AMS) and China's National Defense University (NDU).[6] Journal articles by PLA-affiliated authors also provide insights into how the PLA views biological security and developments in biotechnology. Furthermore, this analysis includes an examination of media articles from PLA publications like the *PLA Daily*.

The Growing Strategic Importance of Biological Security

One of the most common themes in PLA writings on these topics has been an emphasis on the impact that biological security issues may have on China's national security and military strategy. Chinese officials, including Xi Jinping, have listed biosecurity as a security challenge alongside other issues like climate change and cybersecurity.[7] Recent editions of some of China's most authoritative military publications, including the *Science of Military Strategy*, also mention the biological domain (*shengwu lingyu*, *shengwuyu*, or *shengwukongjian*), reflecting the PLA's growing interest and awareness of the topic even before the Covid-19 pandemic.[8]

- The 2001 PLA AMS edition of the *Science of Military Strategy* does not highlight the biological domain but does mention biological weapons alongside nuclear and chemical weapons.[9]
- The 2006 PLA NDU *Science of Campaigns* describes how developments in military technologies, including biological weapons, "have triggered new changes in the internal structures of the military and in the way military operations are conducted."[10]

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6 For more on the AMS, see Joel Wuthnow, "China's 'New' Academy of Military Science: A Revolution in Theoretical Affairs?" Jamestown Foundation, China Brief, January 18, 2019.

7 "Xi Jinping zai boao yazhou luntan 2022 nian nian hui kaimu shi shang fabiao zhuzhi yanjiang" [Xi Jinping Delivers a Keynote Speech at the Opening Ceremony of the Boao Forum for Asia Annual Conference 2022], Ministry of Foreign Affairs of the People's Republic of China (PRC), April 21, 2022. For another official Chinese view of the intersection of biological security and national security, see Li Zhanshu, "Zai shengwu anquan fa shishi zuotan hui shang de jianghua" [Speech at the Symposium on the Implementation of Biosecurity Law], China National People's Congress, April 1, 2021.

8 See also the timeline in Elsa B. Kania and Wilson VornDick, "Weaponizing Biotech: How China's Military Is Preparing for a 'New Domain of Warfare,'" Defense One, August 14, 2019.

9 Ge Zhenfeng, ed., *Zhanlue xue* [Science of Military Strategy] (Beijing: Military Science Press, 2001). The 2004 *Science of Second Artillery Campaigns* also primarily lists biological weapons alongside nuclear and chemical weapons.

10 Zhang Yuliang, ed., *Zhanyi xue* [Science of Campaigns] (Beijing: National Defense University Press, 2006), trans. China Aerospace Studies Institute, *Science of Campaigns (2006)* (Washington, D.C.: China Aerospace Studies Institute, 2020).

- The 2013 PLA AMS edition of the *Science of Military Strategy* primarily mentions biological security in the context of the military preventing potential biological accidents and providing medical aid.[11]
- The 2015 PLA NDU edition of the *Science of Military Strategy* mostly mentions biological weapons alongside nuclear and chemical weapons.[12]
- The 2017 PLA NDU edition of the *Science of Military Strategy* adds an entire section on the biological domain for the first time.

The 2020 PLA NDU edition of the *Science of Military Strategy* continues to include a section on the growing risks in the biological domain, with the authors emphasizing that biotechnology is "one of the fastest-growing and cutting-edge new military fields." The text also stresses that potential future capabilities in the biological domain "can not only bring biological damage to specific targets and people, but also brings large-scale diffusion effects and deterrent attacks."[13] Furthermore, the 2020 edition notes that China should "actively participate in the international biological conventions and strengthen discourse power [*huayuquan*] in the formulation of rules," demonstrating the PLA's desire for China to play a leading role in the establishment of a vision for global health that better supports the CCP's broader biological security interests.[14]

Authors affiliated with the PLA have also studied the growing importance of biotechnology in the context of military affairs.[15] For example, a 2016 article in *China Military Science*, an AMS publication generally considered as the most authoritative PLA journal, examines the impact of biotechnology on future warfare. The authors conclude the following: "Modern biotechnology will open up new combat methods on the basis of conforming to information warfare, which will reduce war violence more efficiently than information technology and can effectively achieve political goals. It is bound to be favored by war subjects and promote the transformation of forms of war."[16]

Potential Military Applications of Biotechnology

PLA-affiliated authors recognize the role that biotechnology capabilities could play in future military contexts. Although these new biological weapons [*shengwu wuqi*] are unlikely to be developed and used in combat in the near term, PLA sources have considered the ways that they could be applied to military conflict in the future. For example, the 2020 NDU *Science of Military Strategy* describes future biotechnology capabilities that might affect an opponent's combat effectiveness. These potential future capabilities include "genetic weapons [*jiyin wuqi*] targeting genes, genomes, and proteomes; brain-controlled weapons that can control target behaviors; as well as biotechnology weapons [*shengwu keji wuqi*] targeting the cognitive and nervous systems, energy metabolism, physical fitness, single or multiple physiological functions,

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11 Zhang, *Zhanyi xue*; and China Aerospace Studies Institute, trans., *Science of Military Strategy (2013)* (Washington, D.C.: China Aerospace Studies Institute, 2021).

12 Xiao Tianliang, ed., *Zhanlue xue* [Science of Military Strategy] (Beijing: National Defense University Press, 2015).

13 Xiao Tianliang, ed., *Zhanlue xue* [Science of Military Strategy] (Beijing: National Defense University Press, 2020), trans. China Aerospace Studies Institute, *In Their Own Words: Science of Military Strategy (2020)* (Washington, D.C.: China Aerospace Studies Institute, 2022), 167.

14 Ibid., 174.

15 For an example, see Zou Wei and Liu Zhanfeng, "Xiandai shengwu jishu: Xin yi lun junshi biange de zhu yinqing" [Modern Biotechnology: Main Engine of a New Round of Revolution in Military Affairs], *Journal of Naval University of Engineering* 12, no. 1 (2015): 42.

16 Li Hongjun and Guo Jiwei, "Shi xi xiandai shengwu keji dui weilai zhanzheng xingtai de yingxiang" [An Analysis of the Impact of Modern Biological Technology on Future Forms of War], *China Military Science*, no. 3 (2016): 34.

and specific populations."[17] The text does not convey that China will use these weapons but instead seems to focus on a general discussion of what future military competition in the biological domain could look like.

Chinese sources have also discussed the intersection of genetics and military capabilities.[18] In a 2021 *PLA Daily* article, the authors reached the following conclusion: "If gene editing is applied to the development of biological weapons, it means that developers can modify genes to obtain new pathogenic microorganisms according to their own needs, or implant biological gene fragments with different characteristics and modify existing biological warfare agents."[19] In addition, journal articles by PLA-affiliated authors seem to have considered the potential threats from dual-use biotechnology [*liangyong shengwu jishu*].[20]

PLA Involvement in China's Past Global Health Initiatives

Given the perceived emerging threats in the biological domain, China has incorporated global health and biotechnology initiatives into its military activities. It also has pursued military-medical diplomacy efforts to help train, and in some cases support, foreign countries' medical operations in times of need. The PLA, for example, has played an active role in executing China's foreign policy strategy during the Covid-19 pandemic by delivering masks and vaccines to other countries within and beyond China's immediate periphery.

Chinese Global Health Initiatives to Combat Biological Security Threats

As China seeks great-power status, Chinese officials and sources have promoted CCP foreign policy initiatives and slogans that attempt to position the country as a leader in global health. China's Health Silk Road, which was originally announced by Xi Jinping in 2016, has called for greater international cooperation in global health among countries participating in the Belt and Road Initiative. One researcher affiliated with China's Central Party School has argued that the Health Silk Road will "inject stronger motivation into the building of a human health community."[21] Xi has also promoted the idea of a "community of common health for mankind" [*renlei weisheng jiankang gongtongti*] during the Covid-19 pandemic.[22] The *PLA Daily* has published pieces promoting these efforts, reflecting the PLA's awareness of a potential connection between global health initiatives for Covid-19, broader Chinese diplomatic priorities, and CCP propaganda.[23]

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17 Xiao, *Zhanlue xue* (2020), 169.

18 For an example, see Xin Chao, "Jiyin wuqi—Buneng dakai de panduola mo he" [Genetic Weapons—Pandora's Box that Can't Be Opened], *National Defense*, no. 11 (2013).

19 Wang Houwen and Zhang Zhaoxing, "'Shendu keji hua' dai lai zhanzheng xin xingtai" ["Deep Technology" Brings New Forms of Warfare], *PLA Daily*, August 13, 2021.

20 For an example, see Jiang Liyong et al., "Shengwu ji xiangguan de liangyong shengwu jishu fengxian pinggu yu fangkong celüe" [Risk Assessment and Countermeasure Strategy of Dual-Use Biotechnology Related to Biological Agents], *Military Medical Sciences*, no. 10 (2020). The authors are affiliated with the AMS.

21 "Ren ji tianxia gongxiang weilai—Quanqiu weisheng zhili de zhongguo dandang" [Benefiting the World and Sharing the Future—China's Role in Global Health Governance], Xinhua, May 28, 2018; and Zhao Lei, "Jianshe jiankang sichouzhi lu zhuli renlei weisheng jiankang gongtongti" [Build a Health Silk Road to Help the Health Community of Mankind], *Guangming Daily*, October 19, 2020.

22 See, for example, "Xi Calls for Building Community of Common Health for Mankind," Xinhua, March 21, 2020.

23 Zhang Weipeng, "Tuidong goujian renlei weisheng jiankang gongtongti de zhongguo gongxian" [China's Contribution to Promoting the Building of a Community of Health for Mankind], *PLA Daily*, April 14, 2021; and Chen Xiao, "Wanshan quanqiu weisheng zhili tixi de zhongguo dandang" [China's Role in Improving the Global Health Governance System], *PLA Daily*, June 1, 2021. Zhang and Chen are affiliated with the China Institute of International Studies (CIIS) Research Center for Xi Jinping Thought on Diplomacy. CIIS is a research institute under the PRC Ministry of Foreign Affairs.

In addition, some PLA sources have promoted the possible applicability of China's "community with a shared future for mankind" in the biological domain while indirectly criticizing Western countries' global health practices. In a 2022 article, scholars from China's National University of Defense Technology stressed the following: "Against the background that Western governance theories and practices have gone bankrupt…China's plan based on the concept of a community with a shared future for mankind will eliminate the ever-increasing outbreak of major infectious diseases."[24] Since the beginning of the Covid-19 pandemic, several Chinese officials also have criticized the United States' response and spread disinformation about the United States being the origin of the virus.[25]

PLA Military Medical Diplomacy

China has advanced its military interests in the biological domain through diplomacy. Chinese military diplomacy activities, which include medical engagements, have increased since Xi Jinping came to power.[26] Such activities have included not only visits by high-level PLA officials and joint exercises with foreign militaries but the deployment of PLA troops abroad to participate in medical missions.[27] In 2014, for example, China sent over one hundred troops to Liberia to help prevent the spread of Ebola.[28] Troops reportedly helped establish an Ebola treatment center and provided anti-pandemic training to local medical staff.[29] In 2017 the PLA helped establish an infectious disease monitoring system in Sierra Leone, which the president of the PLA Academy of Military Medical Sciences at the time, Zhang Shitao, reportedly explained "supports China's ability to react to imported infectious diseases and international public health incidents."[30] The PLA has also participated in joint military exercises with foreign militaries focused on medical diplomacy. Recent examples include the China-Vietnam Peace Rescue 2021 joint medical exercise, peacekeeping exercises in Mali, and the PLA's joint humanitarian medical rescue Peace Train–2022 exercise with Laos.[31] In addition, the PLA's *Peace Ark* hospital ship has been sent on humanitarian assistance and disaster relief (HADR) missions to support countries recovering from national disasters.[32] The *Peace Ark* is estimated to have treated over

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24 Lu Lang and Xu Nengwu, "Renlei mingyun gongtongti shi yu xia de quanqiu shengwu anquan zhili—Xianzhuang fenxi yuanyin tanxi yu lujing xuanze" [Global Biosafety Governance from the Perspective of a Community with a Shared Future for Mankind], *Journal of Xiangtan University (Philosophy and Social Sciences)*, no. 2 (2022): 115.

25 For a Chinese analysis of the United States' response to Covid-19, see Wang Ping, "Meiguo xinguan feiyan yiqing weiji yingdui jianshi" [Disconnection between Strategy and Reality: A Survey of America's Response to the Covid-19 Pandemic Crisis], *Peace and Development*, no. 3 (2020).

26 Kenneth Allen, Phillip C. Saunders, and John Chen, *Chinese Military Diplomacy, 2003–2016: Trends and Implications* (Washington, D.C.: National Defense University Press, 2017).

27 For an overview of China's global health efforts, see Wissemann, "Great (Soft) Power Competition."

28 Meia Nouens, *The Evolving Nature of China's Military Diplomacy* (London: International Institute for Strategic Studies, 2021), 5; and Yinying Lu et al., "Chinese Military Medical Teams in Ebola Outbreak of Sierra Leone," *Journal of the Royal Army Medical Corps* 162, no. 3 (2016): 198–202.

29 In response to the Ebola outbreak in 2014, BGI Group, which has collaborated with the PLA, offered "sequencing equipment and testing reagent for free and dispatched a team of professionals to the capital of Sierra Leone to assist the China disease control team with samples testing, technical support, and training." See "BGI's 'Unstoppable' Efforts to Help the Global Community Fight Public Health Emergencies," BGI, May 8, 2021; "China Tackles Ebola in Liberia," *Global Times*, November 19, 2014; and Tan Yingzhi, "Team Returns Home after Fighting Ebola in Liberia," *China Daily*, January 17, 2015.

30 "PLA Completes Monitoring System for Infectious Diseases in Sierra Leone," Embassy of the PRC in the Republic of South Africa, Press Release, September 11, 2017.

31 Ministry of National Defense (PRC), "Overseas Operations"; and Kenneth Allen, "The PLA's Military Diplomacy in Advance of the 20th Party Congress (Part Two)," Jamestown Foundation, China Brief, October 4, 2022.

32 For more on the Peace Ark, see Timothy R. Heath, "China Maritime Report No. 8: Winning Friends and Influencing People: Naval Diplomacy with Chinese Characteristics," China Maritime Studies Institute, CMSI China Maritime Reports, September 2020.

230,000 patients in 43 countries over the last fourteen years.[33] Chinese sources have described how these activities give the ship "the unique diplomatic advantages of global public goods, such as wide application scope and low political sensitivity."[34]

The PLA during the Covid-19 Pandemic

The PLA has demonstrated an interest in playing a significant role in combating the spread of Covid-19 in other countries.[35] A team led by a researcher from the Beijing Institute of Biotechnology, which is affiliated with the AMS, helped develop one of China's early Covid-19 vaccines.[36] The PLA also has helped deliver vaccines and medical equipment abroad. In a speech at the 2021 Global Health Summit, Xi Jinping described how China provided "vaccine assistance to more than 80 developing countries in need and exported vaccines to 43 countries," as well as "supplied more than 280 billion masks, 3.4 billion pieces of protective clothing, and 4 billion testing kits to the world."[37] This effort is evident in the PLA Air Force's support for vaccine deliveries to Vietnam, Cambodia, and the Philippines.[38] The PLA has also delivered Covid-19 vaccines to foreign militaries, beginning with the Pakistan Army in early 2021.[39] PLA medical teams continued year-long deployments at local hospitals in foreign countries during the Covid-19 pandemic.[40] For example, a Chinese military medical team that arrived in Ethiopia in January 2020 reportedly supported the General Hospital of the Ethiopian National Defense Force. The team remained after the outbreak of Covid-19, providing pandemic support and helping establish a Covid-19 testing laboratory for the Ethiopian military.[41] In addition, the PLA is reported to have helped construct a Covid-19 lab in Myanmar.[42]

Potential Motivations behind China's Global Health Ambitions

With the PLA's noticeable attention to issues in the biological domain, Beijing will likely place greater emphasis on biotechnology and health diplomacy in its future military strategy, especially following the Covid-19 pandemic. Describing biological security as a domain at the "strategic commanding heights," PLA sources clearly convey a growing interest in issues related to biotechnology and emerging biological threats. The PLA's evolving activities and ambitions in global health to respond to biological security challenges also signal the Chinese leadership's

[33] Jiang Chenglong, "Peace Ark Begins Journey Home," *China Daily*, November 20, 2022.

[34] Yin Yanxi, "'Haiyang mingyun gongtongti' yu xia de gonggong weisheng waijiao—Yi haishang yiyuan chuan wei li" [Public Health Diplomacy from the Perspective of the "Maritime Community of a Shared Future"—A Case Study of Marine Hospitals], *Public Diplomacy Quarterly*, no. 3 (2020). Yin is affiliated with the Naval Military Medical University.

[35] For a thorough report on the PLA medical system's efforts to combat Covid-19, see Heidi Holz and Brian Waidelich, "Rx PLA: The PLA Medical System's Role in China's Efforts to Fight COVID-19," CNA, April 2022.

[36] Dyani Lewis, "China's Coronavirus Vaccine Shows Military's Growing Role in Medical Research," *Nature*, September 11, 2020.

[37] "Xi Jinping zai quanqiu jiankang fenghui shang de jianghua (quanwen)" [Remarks by Xi Jinping at the Global Health Summit (Full Text)], Xinhua, May 21, 2021.

[38] "FALSE: China Delivered Vaccines by Military Plane only to the Philippines," Rappler, March 1, 2021; and Laura Zhou, "China Delivers More Covid-19 Vaccines to Vietnam on Eve of Kamala Harris Trip," *South China Morning Post*, August 24, 2021.

[39] Amber Wang, "Coronavirus: People's Liberation Army Provides Covid-19 Vaccines to Pakistani Military," *South China Morning Post*, February 7, 2021. For more information on the PLA's role in supplying Covid-19 vaccines to foreign militaries, see Chao Deng and Joe Parkinson, "China's Army Furnishes Foreign Militaries with Covid-19 Vaccines," *Wall Street Journal*, November 8, 2021.

[40] Helena Legarda, "The PLA's Mask Diplomacy," MERICS, August 3, 2020.

[41] Ibid.; and "China's 6th Military Medical Experts Team to Ethiopia Returns Home," China Military Online, May 21, 2021.

[42] Legarda, "The PLA's Mask Diplomacy."

willingness to use the PLA to become a more active player in international health initiatives. These developments suggest the following potential motivations behind China's actions.

The Development of Power-Projection Capabilities

The PLA already appears to be using its participation in Chinese global health initiatives to further a key objective: expanding and normalizing its presence and operations abroad. Even the PLA's deployment to Africa to counter Ebola can be viewed not just as medical-military diplomacy but as experience for future operational deployments to the continent. While we found no explicit PLA discussions of this hypothetical motivation, future PLA medical deployments of a similar nature could indeed have such a motivation, given China's global basing push in recent years. These activities provide experience and familiarity for military operations beyond China's borders. Military training exercises that focus on global health operations, in addition to HADR missions, also give the PLA the opportunity to observe how other militaries respond to global health situations. U.S. researchers have previously argued that China's military diplomacy ambitions could not only help the PLA improve its military capabilities but also enable China to influence its security environment.[43]

A More Responsible Major Power in Global Health

The PLA's growing desire to play a greater role in global health initiatives may also enhance the CCP's international reputation as an involved actor that is willing to help combat shared global challenges. Gaining more influence in this sphere, however, may also increase China's platform for suggesting changes to global health governance.[44] For example, Chinese military sources have connected the Covid-19 pandemic response to the viability of the current governance system, with one researcher affiliated with the PLA National University of Defense Technology's School of International Relations making the following argument: "The destructive power of biological threats depends on the 'shortcomings' in the global epidemic prevention and control chain. To deal with biological threats, it is urgent to strengthen global biosecurity governance."[45] During a speech at the 2021 Global Health Summit, Xi Jinping specifically declared that "the pandemic is a concentrated test of the global health governance system."[46]

Chinese sources have described how Western countries' pandemic responses reveal problems in the current international health system. While some sources have criticized U.S. activities in biotechnology and called for greater scrutiny of U.S. ambitions in this domain, others have broadly criticized the United States' handling of the pandemic.[47] PLA sources have stressed the importance of China having greater input and influence on global health. For example, one author from the PLA's NDU argues in a 2020 article that "developing countries, including China, have limited discourse power in the formulation of international biosafety rules and are subject

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43 Allen, Saunders, and Chen, *Chinese Military Diplomacy, 2003–2016*.

44 For an analysis of China's efforts to shape its international image in global health, see Nadège Rolland, "China's Pandemic Power Play," *Journal of Democracy* 31, no. 3 (2020): 25–38.

45 Cui Jianshu, "Quanqiu shengwu anquan zhili de zhuti zeren yu linian yinling" [Subject Responsibility and Concept Guidance of Global Biosecurity Governance], *People's Tribune*, no. 15 (2022): 17.

46 "Xijinping zai quanqiu jiankang fenghui shang de jianghua (quanwen)."

47 Wang and Zhang, "'Shendu keji hua' dailai zhanzheng xin xingtai."

to greater restraints."[48] These views are shared by non-PLA Chinese experts. For example, an academic affiliated with the CCP's Central Party School argues in a 2020 *Study Times* article that "the importance of discourse power in global health governance is unprecedented, and the effect of health governance has become an important stage for displaying 'soft power.'" The author later adds: "The new concepts and new initiatives proposed by my country have pointed out the right direction for improving global health governance capacity and enhancing the level of international cooperation in fighting the disease."[49]

Continued Emphasis on Developments in China's Domestic Biotechnology Capabilities

Growing PLA and broader PRC attention toward biological security threats will likely lead to Chinese officials encouraging significant advancements in China's biotechnology sector. In 2021, Xi Jinping hosted a Central Committee Politburo study session on developing China's biological security. During a speech at the session, he reportedly emphasized that China should "accelerate the promotion of biotechnology innovation and industrial application, promote the self-reliance and self-improvement of science and technology in the field of biological security, [and] build national biological security strategic scientific and technological power."[50]

The 2020 NDU *Science of Military Strategy* also notes the importance of enhancing domestic biotechnology capabilities. When discussing the importance of promoting military-civil fusion and "seizing the commanding heights of military conflicts in the biological field," the authors stress that the "development of military biotechnology must make full use of biotechnology resources of the whole society to promote the deep integration of military and civilian development in the biological field."[51] Such developments are especially likely, given that Chinese sources have emphasized that areas of military-civil fusion should expand to issues such as "space, network, and other fields, and deepen into information technology, biotechnology, nuclear protection, and other areas."[52] Meanwhile, Chinese sources have also stressed the importance of improving biosecurity awareness more broadly, especially since the outbreak of the Covid-19 pandemic.[53]

Biotechnology Research and Data Collection Opportunities Threatening National Security

In the context of the changing security environment in the biological domain, China has been pursuing research activities in biotechnology to enhance national security and potentially

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48 Guo Xiuqing, "Zongti guojia anquan guan zhidao xia de shengwu anquan zhili" [Biosecurity Governance under the Guidance of the Overall National Security Concept], *Social Sciences Review*, no. 7 (2020): 9–10.

49 Qu Pengfei, "Yingdui fengxian tiaozhan wanshan quanqiu weisheng zhili" [Addressing Risk Challenges and Improving Global Health Governance], *Study Times*, August 21, 2020. The Study Times is affiliated with China's Central Party School.

50 "Xi Jinping zhuchi zhonggong zhongyang zhengzhi ju di sanshisan ci jiti xuexi bing fabiao zhongyao jianghua" [Xi Jinping Presided Over the 33rd Collective Study of the Political Bureau of the CPC Central Committee and Delivered an Important Speech], Central People's Government (PRC), Press Release, September 29, 2021.

51 Xiao, *Zhanlue xue* (2020), 173.

52 "Shenru guanche 'si ge quanmian' quanli tuijin junmin ronghe shendu fazhan—Jundui renda daibiao xuexi Xi zhuxi zhongyao jianghua tihui" [Thoroughly Implement the "Four Comprehensives" to Fully Promote the In-Depth Development of Military-Civil Integration—the Experience of Military People's Congress Deputies Learning from Xi Jinping's Important Speech], China Military Online, March 13, 2015. See also Luo Yongguang, "Shishi junmin ronghe fazhan guojia zhanlüe tuijin jingji jianshe he guofang jianshe ronghe fazhan" [Implement the National Strategy for Military-Civil Fusion and Promote the Integrated Development of Economic Construction and National Defense Building], *China Military Science*, no. 1 (2016): 36.

53 For an example, see Zhu Kangyou, "Ba shengwu anquan naru guofang jiaoyu tixi" [Incorporate Biosecurity into the National Defense Education System], *Advance*, no. 6 (2020): 34–36, 39.

strengthen the PLA's combat effectiveness. Researchers like Elsa Kania and Wilson VornDick have assessed that the PLA may be interested in researching CRISPR technology for gene editing.[54] China's military-civil fusion strategy has led observers to wonder whether genetic data may be shared with the PLA or is used only for civilian research purposes. Analysts have paid greater attention to the PLA's collaboration with the genomics company BGI, which, according to Reuters, "has worked with the Chinese military to improve 'population quality' and on genetic research to combat hearing loss and altitude sickness in soldiers."[55] Such concerns are especially noteworthy given the growing criticism of China collecting DNA from Tibetans and Uighurs, potentially to improve facial recognition technology.[56] Biotechnology research collaborations between the PLA and universities abroad have also raised national security concerns.[57]

Conclusion and Possible Future Actions

These PLA sources and activities in the biological domain demonstrate the CCP's growing commitment to better understanding the potential military applications of biotechnology. PLA sources, ranging from authoritative military texts to articles published by PLA media outlets, demonstrate a growing interest in issues related to biotechnology and the potential role of biological capabilities in future military conflicts. The PLA's activities in global health, including joint military health exercises and Covid-19–related support abroad, further reveal the CCP's broader desire to become more engaged in global health initiatives, potentially to gain a military advantage. These developments have implications for broader Chinese foreign policy goals that may have a direct impact not only on the United States' national security but also on its reputation as a great power capable of helping other countries combat shared global challenges, including threats in the biological domain. These challenges are likely to remain even after the Covid-19 pandemic, as Chinese sources continue to argue that Western countries' responses to the pandemic demonstrate a need to reform existing global health governance systems to better reflect the ideas of rising powers like China.

Given these developments, U.S. officials should consider the following policy options that could allow the United States to best respond to changes in Chinese thinking and behavior in the biological domain.

Greater collaboration between the United States' national security and biotechnology communities. The United States should encourage greater collaboration between its national security and biotechnology communities to exchange findings, share resources, and provide the context necessary to understand the PLA's goals for biotechnology. Foreign policy analysts may lack the knowledge of biological sciences necessary to fully understand biotechnology developments in China, and such exchanges and collaboration would bridge this gap. Engaging with the U.S.

54 Kania and VornDick, "China's Military Biotech Frontier"; and Ken Dilanian, "China Has Done Human Testing to Create Biologically Enhanced Super Soldiers, Says Top U.S. Official," NBC News, December 3, 2020. CRISPR is an acronym for clustered regularly interspaced short palindromic repeats, a family of DNA sequences.

55 Kirsty Needham and Clare Baldwin, "China's Gene Giant Harvests Data from Millions of Women," Reuters, July 7, 2021, cited in Barnes, "U.S. Warns of Efforts by China to Collect Genetic Data."

56 "China: New Evidence of Mass DNA Collection in Tibet," Human Rights Watch, September 5, 2022; and Sui-Lee Wee and Paul Mozur, "China Uses DNA to Map Faces, with Help from the West," *New York Times*, December 3, 2019. See also Yvonne Lau, "China's Extensive Use of Genetic Information Sounds a Warning," Australian Strategic Policy Institute, Strategist, September 30, 2022.

57 See, for example, Kirsty Needham and Stine Jacobsen, "Monkey-Brain Study with Link to China's Military Roils Top European University," Reuters, November 18, 2021.

scientific community would also help government officials and analysts in the national security community better understand which advancements in biotechnology could have significant implications for China's future combat effectiveness.

Enhanced cooperation with U.S. allies on the intersection of PLA strategy, global health, and biotechnology. The PLA's desire to enhance its "discourse power" in the biological domain suggests that it will support the CCP's broader efforts to increase China's influence in global health initiatives. The United States should engage with its allies and exchange information on the PLA's growing interests in biotechnology, global health, and the biological domain more broadly. While such cooperation would help increase global awareness and international monitoring of future PLA uses of biomedical data, the United States and its allies should play a greater role in shaping international norms related to global health and biological security.

Dialogue between the U.S. Department of Defense and the PLA on global health cooperation. The U.S. Department of Defense should consider increasing its interactions with the PLA to specifically discuss global health issues. The deteriorating bilateral relationship and China's disinformation campaign on the origins of Covid-19 will continue to present significant challenges for such engagement. However, the persistent spread of the virus demonstrates how important it is for both countries to view global health as a potential area of cooperation.

Studies of the intersection of Chinese military strategy and biological security. Chinese military thinking on biological security and potential Chinese military applications of biotechnology remain understudied topics in the United States. While studies of the potential security threats that China's domestic biotechnology advancements pose for U.S. national security are becoming more common, they should be supplemented with additional studies of biotechnology and its application within the PLA. Future research on Chinese biotechnology laboratories that collaborate with the PLA, in addition to research on their sources of funding, could also provide insights into the role of China's military-civil fusion in this context. Such studies not only would help analysts better understand China's long-term view of the PLA's biotechnological capabilities but could help policymakers put CCP leaders' support for such advancements in China's domestic biotechnology sector in a military context. These studies would also better prepare the U.S. government to explain the PLA's role in the Chinese biotechnology industry to a broader audience.

NBR THE NATIONAL BUREAU *of* ASIAN RESEARCH

Seattle and Washington, D.C.

600 UNIVERSITY STREET, SUITE 1012
SEATTLE, WASHINGTON 98101 USA
PHONE 206-632-7370, FAX 206-632-7487

1819 L ST NW, NINTH FLOOR
WASHINGTON, D.C. 20036 USA
PHONE 202-347-9767, FAX 202-347-9766

NBR@NBR.ORG, WWW.NBR.ORG