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## Analysis of Development Trends and Recommendations for Gene Editing Technology: Postprint

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### Abstract

Gene editing technology has ignited a wave of global research and development, with CRISPR technology emerging as the most promising genome editing technology. It has been rapidly implemented in applications such as livestock and poultry breeding, biomedical research and development, with related clinical trials already initiated. Its development has catalyzed new directions for the bio-industry, engendered substantial socio-economic value, and the industrial landscape has begun to take shape. China has consistently placed high priority on gene editing, maintaining pace with international advancements in scientific research and achieving a series of breakthrough accomplishments. Furthermore, in application domains of gene editing including large animal model construction and disease treatment clinical trials, China has entered the international first echelon. Moving forward, China must further advance original technological innovation to gain international discourse power in this field, and optimize the policy environment to guarantee the rapid, healthy, and orderly development of downstream applications of gene editing technology in China.

### Full Text

#### Trends and Development Bottleneck Analysis of Gene Editing Technology

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### Abstract

Gene editing technology has spurred a global research and development boom, with CRISPR technology emerging as the most promising genome editing tool. It has rapidly found applications in livestock breeding, biomedical research and

development, and related clinical trials have already commenced. This technological advancement has driven new directions in bio-industry development, created enormous socioeconomic value, and established a preliminary industrial framework. China has consistently prioritized gene editing, keeping pace with international developments in scientific research and achieving a series of breakthrough results. Simultaneously, China has entered the international first echelon in applied fields such as large animal model construction and clinical trials for disease treatment. Moving forward, China must further promote original technological innovation to seize international discourse power in this domain while optimizing the policy environment to ensure rapid, healthy, and orderly development of downstream applications of domestic gene editing technology.

**Keywords:** biotechnology; gene editing; development trends; trend analysis; patent analysis

The emergence of gene editing technology marks another milestone in life science development, propelling transformative advances across the field. To date, three generations of site-specific gene editing tools have been developed: zinc finger nucleases (ZFN), transcription activator-like effector nucleases (TALEN), and clustered regularly interspaced short palindromic repeats (CRISPR) technology. These tools have been widely applied across all aspects of life science research, repeatedly earning spots on Science's Top Ten Breakthroughs of the Year, Nature Methods' Method of the Year, and MIT Technology Review's Top Ten Breakthrough Technologies. Notably, CRISPR technology and related achievements have been selected for Science's Top Ten Breakthroughs an unprecedented three times (2013, 2015, and 2017).

The simplicity and versatility of gene editing technology, particularly the technical advantages of CRISPR, have attracted widespread attention from the scientific community, leading to rapid growth in related research. In 2012, Jennifer Doudna's team at the University of California, Berkeley formally proposed that the CRISPR-Cas system could enable gene editing [?]. In early 2013, Feng Zhang's team [?] pioneered the use of CRISPR technology to edit eukaryotic cell genomes, sparking a global wave of research and development on genome editing technology. Subsequently, multiple research teams applied CRISPR technology to plants, animals, and human cells, demonstrating its broad applicability.

## 1. Rapid Innovation in CRISPR-Based Gene Editing Technology

Technological breakthroughs and iterative updates represent the current focus of gene editing research and development, with directions that can be summarized as improvements in precision, enhanced safety, and the development of novel gene editing technologies.

### 1.1 Gene Editing Enters the Era of “Point-to-Point” Precision Editing

Gene editing technology continues to advance toward greater precision, with multiple breakthroughs pushing the field into a point-to-point era. Researchers at Harvard University and the MIT-Harvard Broad Institute developed novel base editors BE3 [?] and ABE7 [?] based on CRISPR/Cas9, achieving the first reciprocal conversion between G•C and A•T base pairs in DNA. Meanwhile, the Broad Institute [?] also utilized CRISPR/Cas13 technology (REPAIR) to effectively achieve single-base editing of adenine (A) in RNA. These breakthroughs enable precise targeting and editing of single mutations in DNA and RNA, providing important tools for treating point mutation genetic diseases.

Chinese scientists have systematically optimized this base editing technology. A collaboration between ShanghaiTech University and the Chinese Academy of Sciences’ Max Planck Partner Institute for Computational Biology [?] constructed a novel Cpf1-based base editor (Cpf1-BE) that enables base editing in A/T-rich regions, achieving precise conversion of cytosine (C) to thymine (T) and complementing existing single-base editing tools. The same team also developed a human APOBEC3A-based base editor (hA3A-BE) that enables efficient single-base editing of methylated cytosine (mC) to thymine (T) in highly methylated genomic regions [?], providing new tools, methods, and insights for comprehensive and in-depth applications of base editing systems in basic and clinical research.

### 1.2 Addressing Off-Target Effects and Safety Concerns

Off-target effects and other stability and safety issues of gene editing technology have been discovered through research, with substantial efforts devoted to developing tools for precise control of gene editing. Stanford University [?] found that antibodies against Cas9 are common in humans, suggesting that CRISPR/Cas9-based gene therapy may trigger autoimmune responses. Research from the Karolinska Institute [?] and Novartis Institutes for BioMedical Research [?] both indicated that clinical applications of gene editing technology may increase cancer risk. The University of Adelaide and South Australian Health and Medical Research Institute [?] discovered that CRISPR/Cas9 editing of human embryos can cause large DNA fragment deletions. To make the technology safer and more reliable, researchers have primarily modified the Cas9 enzyme in the CRISPR system [?, ?] or developed tools [?] to intervene in the gene editing process, thereby significantly reducing off-target effects. Additionally, the Salk Institute [?] further modified the CRISPR system to create an “epigenetic editing technology” that does not cut DNA but instead silences specific gene expression, demonstrating significant therapeutic efficacy in type I diabetes, kidney injury, and Duchenne muscular dystrophy, thus proposing a new approach to improving gene editing safety.

Chinese scientists have conducted a series of studies addressing the limitations of gene editing technology, particularly CRISPR. For example, they developed

a novel technology that can precisely regulate multiple functions including gene activation, repression, and cleavage, enabling directed intervention in cancer cells through precise control of the CRISPR/Cas9 system [?]. Furthermore, the Chinese Academy of Sciences and Peking University [?] utilized CRISPR/Cas9 technology to target multiple chromosomal loci, achieving selective elimination of entire target chromosomes and providing new strategies for establishing animal models of chromosomal deletion diseases and treating aneuploidy disorders.

### 1.3 Continuous Optimization and Expansion of Gene Editing Technology

Researchers continue to develop different types of nucleases to optimize and expand the CRISPR toolkit, including CRISPR/Cpf1 [?], CRISPR/CasX, CRISPR/CasY [?], CRISPR/C2c2 [?], CRISPR/Cas13b [?], CRISPR/xCas9 [?], and CRISPR/CasRx [?]. Some of these systems, such as CRISPR/Cpf1, have had their gene editing potential confirmed by multiple studies [?]. The development of these new technologies not only helps address the limitations of gene editing technology but also greatly expands its capabilities.

Chinese researchers have focused on further characterizing novel nucleases with application potential. The Institute of Biophysics of the Chinese Academy of Sciences resolved the crystal structure of the C2c2-crRNA (CRISPR-RNA) binary complex and C2c2 in its free state [?], providing an important structural biology foundation for studying the molecular mechanism of C2c2's RNase activity. They further revealed the mechanism of RNA cleavage by C2c2 from a structural perspective [?], paving the way for its application as an RNA editing tool.

### 1.4 Exploration and Development of Novel Gene Editing Technologies

While optimizing existing technologies, researchers are also committed to finding more effective novel gene editing technologies beyond ZFN, TALEN, and CRISPR systems. The MIMIVIRE (mimivirus virophage resistance element) system from giant mimiviruses may have potential for gene editing applications [?], and a new technology based on peptide nucleic acids (PNAs) [?] can edit DNA without cutting it, eliminating off-target risks and potentially performing better in clinical applications.

Although there remains a gap between Chinese scientists and international levels in developing novel gene editing technologies, China has also achieved breakthrough results. In 2016, researchers from Nanjing University internationally pioneered a structure-guided DNA editing technology [?] that removes target sequence limitations from gene editing. Researchers from Sun Yat-sen University and other institutions also developed an RNA editing technology called DICERi [?] that can significantly inhibit target gene expression levels and functions. These achievements are significant for enhancing China's influence in the gene editing field.

## 2. Rapid and Extensive Application of Gene Editing Technology Across Multiple Fields

Genome editing technology has rapidly found applications in livestock breeding and biomedical research and development due to its precision and efficiency. Chinese scientists have conducted extensive explorations, achieving major breakthroughs and international leadership particularly in plant and animal breeding, animal model construction, and clinical trials for disease treatment.

### 2.1 Pioneering Applications in Crop Breeding and Livestock Improvement

Gene editing technology faces relatively low regulatory barriers in agriculture and thus began development earliest. It has been successfully applied to develop new high-yield, high-resistance varieties of tobacco, rice, wheat, and other crops, as well as to improve economically important livestock such as pigs resistant to lethal viruses and cows producing milk containing growth factors.

As early as 2013, the Institute of Genetics and Developmental Biology of the Chinese Academy of Sciences pioneered the use of CRISPR/Cas technology to achieve targeted mutations in rice and wheat genes [?], confirming the technology's applicability for plant improvement and enhancing breeding efficiency, thereby gaining a first-mover advantage in agricultural gene editing. Since then, China has successively achieved efficient and precise single-base targeted mutations in various crops including soybeans, wheat, rice, and corn.

### 2.2 Gene Editing Technology Demonstrates Enormous Potential in Disease Treatment

#### (1) Basic Research

Gene editing technology has demonstrated promising potential in disease treatment, with the U.S. National Institutes of Health (NIH) investing heavily to overcome barriers to its clinical application. Related basic research has achieved effective intervention in various diseases including retinitis pigmentosa [?], leukemia, heart disease, and Duchenne muscular dystrophy [?], and has enabled specific targeted knockout of cancer fusion genes [?] and HIV viral genes [?], advancing disease research progress. Additionally, by combining with advanced biotechnologies such as stem cells and CAR-T, gene editing has facilitated the development and upgrading of gene therapy, regenerative medicine, and cancer immunotherapy. Furthermore, by knocking out all potentially harmful viral genes in the pig genome, gene editing will help overcome major obstacles to using pig organs for human transplantation [?].

China has conducted extensive research on applying gene editing technology to biomedical research and disease treatment, achieving important breakthroughs in treating reproductive, genetic, cancer, and AIDS diseases. Notably, China

was the first to apply CRISPR technology to edit genes in human embryos, successfully repairing the gene causing  $\alpha$ -thalassemia in human embryos [?]. Chinese researchers have also played an important role in correcting pathogenic point mutations in human embryos [?] and confirming the safety and efficacy of gene editing in human germline cells. Moreover, animal models are effective tools for drug development and disease research, and China has leveraged its strengths in this area to establish gene-edited models of goats, pigs, dogs, rats, mice, and other animals. Particularly in the field of primate models, China obtained the world's first pair of gene-engineered monkeys carrying directed mutations [?], a milestone achievement that laid the foundation for constructing disease research models that more closely resemble humans.

## (2) Clinical Trials

Clinical trials for gene editing technology in disease treatment have begun, with breakthroughs expected in 2018 (Table 1 ). In 2017, UCSF Benioff Children's Hospital combined adenovirus (AAV) and ZFN technology to treat Ramsay Hunt syndrome, marking the world's first clinical treatment involving direct in vivo gene editing in humans. The world's first CRISPR-based clinical trial (editing immune cells to treat lung cancer), conducted by China, was also scheduled to conclude in 2018. China's relatively relaxed regulatory policies for clinical trials have provided sufficient space for development in this area. Among the 15 clinical trials registered in U.S. ClinicalTrials.gov, 11 are from Chinese institutions, demonstrating China's first-mover advantage in this field.

**Table 1 Clinical trials using gene editing technology**

Country	Institution/Company Name	Technology	Disease/Condition
USA	National Children's Medical Center, Washington	CRISPR/Cas9	Type 1 neurofibromatosis, central nervous system
USA	University of Pennsylvania	CRISPR, TCR, CAR-T	Multiple myeloma, melanoma, synovial sarcoma, myxoid/round cell liposarcoma
USA	NIH Clinical Center	CRISPR/Cas9	Sickle cell anemia
China	West China Hospital, Sichuan University	CRISPR/Cas9, CAR-T	Metastatic non-small cell lung cancer

Country	Institution/Company Name	Technology	Disease/Condition
China	Nanjing Drum Tower Hospital	CRISPR/Cas9	Gastric cancer, nasopharyngeal carcinoma, T-cell lymphoma, adult Hodgkin lymphoma, diffuse large B-cell lymphoma
China	307 Hospital of PLA	CRISPR/Cas9	HIV-1 infection
China	Prince of Wales Hospital, Hong Kong	CRISPR/Cas9	Gastrointestinal infections
China	Hangzhou Cancer Hospital	CRISPR/Cas9, CAR-T	B-cell leukemia, B-cell lymphoma

*Data source: ClinicalTrials.gov; Search date: July 16, 2018.*

### 3. Gradual Formation of the Global Gene Editing Technology Industry Chain

As research on gene editing technology itself and its applications continues to advance, its industrial structure is gradually taking shape. According to market research firm Markets and Markets, the global gene editing market will grow from \$3.19 billion in 2017 to \$6.28 billion in 2022, with a compound annual growth rate of 14.5%. In terms of technology type, CRISPR technology dominates the global gene editing market. MarketsandMarkets segments the global gene editing market into cell line engineering, genetic engineering, and diagnostic and therapeutic applications, with cell line engineering accounting for the largest share in 2017. Analysis of patent application institutions (Figure 1 [Figure 1: see original paper]) reveals a mix of research institutions and enterprises, indicating that gene editing technology has rapidly transitioned from basic research to commercial application.

#### Figure 1 Organizations of patent applications for gene editing technology in 2008-2017

Currently, commercial applications of gene editing technology primarily include scientific research, pharmaceuticals, and breeding (Figure 2 [Figure 2: see original paper]). The upstream segment consists of universities and technology development institutions that provide patent licensing. The midstream segment comprises product and service suppliers offering reagent development, nucleic acid sequence design and synthesis, and application technology development and transformation—this is the key link converting basic research results into commercial applications. Downstream end-users mainly include biotechnology and pharmaceutical companies, research institutions, and contract research or-

ganizations (CROs). These three segments are closely integrated through collaborations and investments.

## Figure 2 Industry chain of gene editing technology

*Data source: Innography database; Search date: July 3, 2018*

Gene editing breeding does not require introduction of foreign genes and involves relatively fewer ethical issues, so its application potential has emerged first. The application of gene editing in breeding not only reduces the risks associated with genetically modified varieties but also lowers the technical entry barriers, enabling small companies to enter the field. In 2018, the U.S. Department of Agriculture approved CRISPR-derived crops for market entry, creating opportunities for sector development.

Agricultural biotechnology giants have already entered the gene editing breeding field (Table 2). Monsanto obtained the first global license in agriculture for core CRISPR patents from the MIT-Harvard Broad Institute in 2016 to conduct breeding research and development. DuPont and Dow's breeding businesses have merged to form DowDuPont, which holds an important position in the gene editing breeding market (Figure 1). Additionally, Cibus' first gene-edited crop, SU Canola™ (sulfonylurea herbicide-resistant canola), began commercial cultivation in the United States in 2015, and its glyphosate-tolerant flax developed using gene editing technology is expected to be launched in the U.S. market in 2019.

**Table 2 Main companies for application of gene editing technology in breeding**

Company	Technology	Applications/Licensing Status
Monsanto (USA)	CRISPR	Obtained global non-exclusive license for Broad Institute CRISPR patents in agriculture; R&D on corn, soybeans, cotton, and bacteria for yogurt/cheese production
DuPont Pioneer (USA)	CRISPR	Exclusive license for UC Berkeley CRISPR patents in major crops; drought-resistant corn, wheat
Dow Agro-Sciences (USA)	ZFN and CRISPR	EXZACT™ precision genome modification platform; non-exclusive global license agreement with Monsanto
Collectis (France)	TALEN	Potatoes, wheat, soybeans
Recombinetics (USA)	CRISPR	Precision genome modification
Cibus (USA)	TALEN	First gene-edited herbicide-resistant canola commercially grown in USA since 2015; glyphosate-tolerant flax expected 2019

Although China has a first-mover advantage in applied research on gene editing breeding technology, the related industry has not yet formed. Domestic companies primarily focus on technical services. For example, Hangzhou Biogle Biotechnology mainly provides gene editing services for important crop varieties such as rice, soybeans, and corn through collaborations with multiple domestic academies of agricultural sciences and Chinese Academy of Sciences institutes.

### 3.3 Medical Applications of Gene Editing Technology Become Industry Hotspot

The development of disease treatment solutions based on gene editing technology has attracted industry attention, with major multinational corporations including Bayer, Novartis, and Pfizer establishing related businesses. Meanwhile, startups focused on CRISPR and other gene editing technologies have gone public, demonstrating enormous industrial development prospects in this field.

The headquarters of major global gene editing technology companies are all located in the United States, indicating strong U.S. competitiveness in this domain. In terms of technology types, companies employ nearly all three generations of gene editing technologies, though CRISPR remains dominant. Adenovirus or adeno-associated virus technologies are also common. Additionally, the combination of CRISPR technology and CAR-T is a project that U.S. biopharmaceutical companies are competing to pioneer. The three major publicly traded companies in the CRISPR field—Editas Medicine, Intellia Therapeutics, and CRISPR Therapeutics—have all partnered with CAR-T R&D giants to produce blockbuster results (Table 3).

**Table 3 Overview of key international companies of gene editing technology**

Company	Founded	Country	Founders/Key Figures	Technology	Pipeline	Status
Editas Medicine	2013	USA	Jennifer Doudna, George Church	CRISPR-c	LCA and other rare eye diseases, liver cancer, lung cancer, leukemia, muscle diseases	Nasdaq IPO, first gene editing IPO, \$43M Series A, \$120M Series B

Company	Founded	Country	Founders/Key Figures	Technology	Pipeline	Status
Intellia Therapeutics	2014	USA	Jennifer Doudna	CRISPR-c	Leukemia, transthyretin amyloidosis, antitrypsin gene deficiency, HBV, HSC-related diseases	Nasdaq IPO May 2016, second series A, \$70M Series B
CRISPR Therapeutics	2013	Switzerland	Emmanuelle Charpentier	CRISPR-c	Cystic fibrosis, blindness, blood diseases, congenital diseases	Nasdaq IPO, third gene editing IPO, \$44.46M raised
Caribou Biosciences	2011	USA	Jennifer Doudna et al.	CRISPR-c	Liver disease, hemophilia mu-copolysaccharidosis	Nasdaq IPO, \$45M raised
Sangamo Bio-Sciences	1995	USA	Edward O. Lanphier II	ZFN	HIV/AIDS, hemophilia mu-copolysaccharidosis	Nasdaq IPO, \$127M raised

Company	Founded	Country	Founders/Key Figures	Technology	Pipeline	Status
Exonics Therapeutics	2017	USA	Eric Olson	CRISPR-c	Duchenne muscular dystrophy, other neuromuscular diseases	\$54M raised
Homology Medicines	2015	USA	Saswati Chatterjee	rAAV	CD34-positive diseases, cystic fibrosis, DMD, sickle cell anemia	\$49M raised
Poseida Therapeutics	2015	USA	George Church et al.	CAR-T+CRISPR	Multiple myeloma, prostate cancer, -	\$40M total disclosed
LogicBio Therapeutics	2016	USA	Tomer Kariv, Mark Kay	rAAV	Pediatric genetic diseases	\$49M raised
Agenovir	2014	USA	Stephen Quake	CRISPR-c	Cervical cancer, anal warts, CMV, EBV	\$13M raised
eGenesis	2015	USA	George Church, David Russell	CRISPR-c	Xenotransp	\$38M Series A
Universal Cells	2007	UK	Various	CRISPR-c	Universal donor cells	Toronto listed, \$49.8M raised

Company	Founded	Country	Founders/Key Figures	Technology	Pipeline	Status
Horizon Discovery	2007	UK	Chris Torrance, Alberto Bardelli	CRISPR-c	Gene editing cell technology	Euronext listed
Synthego	2012	USA	Various	CRISPR-c	Gene editing improvement technology	\$100M+ raised
Benchling	2012	USA	Various	CRISPR-c	Biotechnology platform search tools	\$13M raised

*Data source: Compiled from public information.*

China has dozens of companies involved in gene editing technology, mostly positioned in the midstream of the industry chain, focusing on kit development and technical support. Their customers primarily come from medical institutions, enterprises, research institutes, and universities, indicating that gene editing technology itself is relatively mature for scientific applications in China (Table 4).

Some companies have already begun preliminary development of disease treatment solutions using gene editing technology. EdiGene, China's first gene editing company, has initially developed novel therapies for cancer, genetic diseases, and infectious diseases. The research by Huang Junjiu's team at Sun Yat-sen University on treating thalassemia with gene editing technology has also partnered with Jinjia Co. for further development. Gosun Bio-Pharmaceutical has collaborated with the Third Military Medical University, Chongqing Medical University, and the Chinese Academy of Sciences to advance development of CRISPR-based targeted drugs that destroy the hepatitis B virus surface antigen coding region.

**Table 4 Overview of key Chinese companies of gene editing technology**

Region	Company	Founded	Business/R&D Focus
Beijing	EdiGene	2013	First Chinese gene editing company; cell therapies for cancer, genetic diseases, infectious diseases
Beijing	Cyagen Biosciences	2006	Gene editing model animals; subsidiary of US Cyagen
Shanghai	Yomo Biotech	2015	Gene editing technical services and products
Guangzhou	Cyagen Biosciences (China)	2010	Gene editing technology platform services, model construction
Guangzhou	Vivo Biotech	2010	Cell therapy and gene therapy for tumors and genetic diseases
Chongqing	Gosun Bio-Pharmaceutical	2015	Original biologics development based on gene editing
Suzhou	Synbio Technologies	2013	Synthetic biology, DNA technology
Hangzhou	Biogle Biotechnology	2014	Gene editing services for rice, soybeans, corn
Hefei	Codon Biotech	2015	Gene editing in healthcare and modern agriculture
Jinan	Weizhen Biosciences	2007	Recombinant proteins, antibodies, research tools; first Chinese CRISPR patent

*Data source: Compiled from public information.*

#### 4. Bottlenecks in China' s Gene Editing Technology Innovation and Application

Although China ranks among the international leaders in gene editing technology application and development, deficiencies remain in original technological innovation and industrialization, primarily manifested in the following aspects.

##### (1) Insufficient Core Technology and Original Innovation, Hindering Market Initiative

Despite significant progress in recent years, China' s gene editing technology faces the awkward situation of lacking original innovation. All stages of the "research-industry-application" chain lack original innovative achievements with independent intellectual property rights. On one hand, core patents for existing gene editing technologies are basically owned by foreign entities. On the other

hand, core product innovations based on gene editing technology, such as therapies, lag behind developed countries like the United States. This situation is highly unfavorable for China to seize the enormous development opportunities brought by this new technological revolution.

### **(2) Incomplete Industry Chain and Weak Industrial Transformation Capability, Hindering Commercialization**

The global gene editing technology industry is gradually forming, with multiple specialized companies going public. While China's basic and applied research in gene editing technology ranks in the world's "first tier," the industry chain remains incomplete, with most companies positioned in the midstream segment. Although transformation work has begun in the clinical treatment field, industrial transformation capability remains relatively weak compared to international advanced levels, and the commercialization process is slower, which is detrimental to competition in the gene editing domain.

### **(3) Absence of Regulatory Measures and Ethical Standards, Constraining Industrial Development and Achievement Transformation**

The rapid emergence and application of gene editing technology pose challenges for regulation. Currently, China's management measures and guidelines for gene editing research mainly include the "Interim Measures for the Management of Human Genetic Resources" (implemented in 1998), the "Ethical Guidelines for Human Embryonic Stem Cell Research" (issued in 2003), and the "Regulations on the Management of Human Genetic Resources (Draft for Review)" drafted by the Ministry of Science and Technology in 2016. Human clinical trials have been authorized by the former National Health and Family Planning Commission to be reviewed and risk-assessed by hospital ethics committees. However, a comprehensive ethical supervision and regulatory system for gene editing technology research and applications has not yet been established, which is not conducive to the standardized development of China's gene editing technology.

## **5. Recommendations for China's Gene Editing Technology Development**

Based on China's current research status and existing problems, the following development recommendations are proposed.

### **(1) Encourage Original Innovation and Develop Gene Editing Technology with Independent Intellectual Property Rights**

Beyond the relatively mature CRISPR system, novel gene editing systems remain to be developed. The technology itself still has considerable room for improvement in terms of targeting precision and efficiency, reducing off-target effects, and addressing many issues before true clinical application. Therefore, policies and funding should encourage and support researchers to explore source technologies and create original gene editing technologies with independent intellectual property rights.

### **(2) Leverage Advantageous Fields and Accelerate Applied Research**

China already leads in multiple gene editing application fields, such as humanized animal model construction, breeding and improvement of important crops and livestock, and clinical trial development. Future efforts should focus on these areas with increased support to consolidate China's research foundation, establish advantageous domains in gene editing technology applications, and compete for initiative and discourse power in this field.

### **(3) Build Comprehensive Platforms to Promote Innovation and Industrialization**

Globally, multiple resource libraries and technology platforms have been established for gene editing technology innovation and application. China should focus on building comprehensive, standardized gene editing technology resource-sharing platforms similar to the Genomic Engineering platform, providing resources such as technical information, gRNA target sites for model organisms, and specific primer designs to effectively improve information resource utilization, promote gene editing technology application and dissemination, and drive technological innovation and industrial transformation.

### **(4) Establish Regulatory and Ethical Standards to Promote Orderly Industrial Development**

As gene editing technology, particularly CRISPR technology, continues to mature, it accelerates global application processes and drives related industry development. China has already secured a first-mover advantage in this field and should promptly formulate ethical standards and regulatory policies that align with national conditions and facilitate transformation of research achievements, accelerating research and translation of gene editing technology for crop improvement and major disease treatment.

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