# Untitled

by Poornima Y

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| 32,451 | 4,579 | 303 | 18 min 18 sec | 35 min 13 sec |
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# Untitled

CRISPR, gene editing, and the designer baby debate

A comprehensive analysis of the ethical, scientific, and societal implications

Abstract

The advent of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology has revolutionized the field of genome editing, enabling precise modifications to the genetic material of living organisms. While offering unparalleled potential for treating genetic diseases, enhancing agricultural yields, and advancing basic biological research, CRISPR's application to human germline editing – inheritable modifications – has ignited intense debate surrounding the concept of "designer babies." This article provides a comprehensive overview of CRISPR technology, its diverse applications, and the complex ethical, social, and regulatory landscape surrounding its use, particularly in the context of human germline manipulation. It addresses the scientific capabilities, potential benefits, inherent risks like off-target effects and mosaicism, and the profound societal implications, including concerns about eugenics, equitable access, and impacts on human diversity. Finally, it surveys the current global regulatory environment. It emphasizes the crucial need for continued interdisciplinary dialogue and responsible innovation to harness CRISPR's potential while safeguarding ethical boundaries and societal values.

Keywords

CRISPR, gene editing, genome editing, germline editing, designer babies, ethics, genetic engineering, human enhancement, genetic diseases, regulation, biotechnology.

## Introduction

The ability to alter the genetic code, the fundamental blueprint of life, has long been a dream of scientists and a subject of both fascination and apprehension for society. For decades, gene therapy relied on methods with limited precision and efficiency. However, the discovery and adaptation of the CRISPR-Cas system, a bacterial defense mechanism, have dramatically shifted this landscape, offering unprecedented accuracy, simplicity, and affordability in genome editing. CRISPR-Cas technology, often described as "molecular scissors," allows scientists to make targeted changes to DNA sequences, opening vast avenues for scientific discovery and therapeutic development.

This remarkable technological advancement brings with it a complex set of opportunities and challenges. On one hand, CRISPR holds immense promise for treating a wide array of devastating genetic diseases by correcting the underlying mutations. On the other hand, the possibility of using CRISPR to modify the human germline—changes that would be passed down to future generations—has ignited a global debate about the creation of "designer babies." This term refers to the hypothetical scenario where human embryos are genetically modified to possess specific desired traits, raising profound ethical, social, and even philosophical questions about human identity, diversity, and the boundaries of scientific intervention.

This article will explore the development of CRISPR technology. It will describe the technology's mechanisms and contrast it with previous gene editing tools. It will then cover its applications, from medicine to agriculture, followed by a focus on human germline editing and the "designer baby" concept. It will discuss the ethical concerns, including safety, equity, eugenics, and human diversity. The article will review the global regulatory environment and the path toward responsible technology development and application.

## Materials and methods

CRISPR-based gene editing focuses on the targeted cleavage of specific DNA sequences. This section will describe the CRISPR-Cas system's mechanism and compare it to earlier genome editing technologies.

### Mechanism of the CRISPR-Cas System

The CRISPR-Cas system comes from a bacterial adaptive immune system designed to protect against viral infections. The system, especially the CRISPR-Cas9 variant, has two components:

Guide RNA (gRNA): This engineered RNA molecule has a spacer sequence (approximately 20 nucleotides) that matches the target DNA sequence, and a constant scaffold sequence that binds to the Cas9 enzyme. The spacer sequence directs the Cas9 enzyme to the specific location in the genome.

Cas9 Enzyme: This DNA-cutting enzyme (nuclease) acts as molecular scissors. Guided by the gRNA, Cas9 creates a double-strand break (DSB) in the DNA.

The process includes these steps:

Target Recognition: The gRNA, with the Cas9 enzyme, scans the host genome for a DNA sequence that matches its spacer sequence. This recognition is helped by a Protospacer Adjacent Motif (PAM) (e.g., NGG for Cas9 from Streptococcus pyogenes), which must be present next to the target site for binding and cleavage.

DNA Cleavage: When the gRNA finds its target sequence, Cas9 cuts both DNA strands, creating a double-strand break.

DNA Repair and Editing: The cell's DNA repair mechanisms then try to fix this break. There are two primary pathways:

Non-Homologous End Joining (NHEJ): This error-prone repair pathway can result in insertions or deletions (indels) at the cut site. This can be used to "knock out" a gene.

Homology-Directed Repair (HDR): If a DNA template with homology to the cut site is provided, the cell can use this template to repair the break, allowing for the insertion of new genetic material or correction of specific mutations.

{Image Suggestion 1: Diagram illustrating the CRISPR-Cas9 mechanism}

A visual representation showing the gRNA guiding Cas9 to the target DNA sequence, the double-strand break, and the two repair pathways (NHEJ and HDR) with their respective outcomes. Resources like the National Institute of General Medical Sciences (NIGMS) (.gov) and ResearchGate offer examples.

Comparison with Previous Gene Editing Technologies

Before CRISPR-Cas systems, Zinc Finger Nucleases (ZFNs) and Transcription Activator-like Effector Nucleases (TALENs) were used for targeted genome editing. These earlier technologies also used engineered nucleases to create double-strand breaks, but they had limitations:

Complexity: ZFNs and TALENs require a unique protein for each DNA target site, which is complex and time-consuming.

Cost: Designing and synthesizing these proteins made ZFN and TALEN applications more expensive.

Efficiency and Precision: ZFNs and TALENs could be less efficient and precise than CRISPR-Cas systems, leading to higher off-target effects.

CRISPR's advantages in ease of design, low cost, and higher efficiency have made it the dominant technology.

{Image Suggestion 2: Graph or table comparing gene editing technologies}

A table or bar graph illustrating the relative ease of use, cost, and efficiency of ZFNs, TALENs, and CRISPR-Cas9. Based on information found in sources like National Institutes of Health (NIH) | (.gov) and ResearchGate.

Results and discussions

CRISPR technology has capabilities that span different areas, offering benefits and ethical dilemmas. This section will explore the applications and discuss the issues surrounding human germline editing.

A. Potential benefits of CRISPR technology

CRISPR's precision has opened new frontiers in medicine, agriculture, and scientific research.

Treating Genetic Diseases:

Somatic Gene Editing: The most common application of CRISPR in humans is treating genetic diseases by editing somatic (non-reproductive) cells. This includes potential therapies for conditions like:

Sickle Cell Anemia and Beta-Thalassemia: These blood disorders are currently being researched in clinical trials using CRISPR.

Cystic Fibrosis: Research explores correcting the mutations in the CFTR gene responsible for this lung disease.

Huntington's Disease and Other Neurodegenerative Disorders: Scientists are investigating CRISPR to target and inactivate genes associated with these conditions.

Cancer Therapies: CRISPR is being employed to enhance adoptive cell therapies like CAR-T cell therapy, where a patient's immune cells are genetically modified to better target and destroy cancer cells. 18 out of 19 CRISPR-based clinical trials for hematologic malignancies focus on CAR-T cell therapies.

{Report Suggestion 1: Table of potential CRISPR gene therapies in clinical trials}

A table summarizing ongoing or recently completed clinical trials using CRISPR for various diseases (Molecular Cancer, according to National Institutes of Health (NIH) | (.gov)).

Agricultural Applications: CRISPR is transforming agriculture, enabling the development of crops with enhanced traits and improved livestock.
Crop Improvement: Modifying crops for increased yield, enhanced nutritional content, resistance to pests and diseases, and tolerance to environmental stresses (like drought) can contribute to global food security. Scientists have used CRISPR to engineer disease-resistant wheat or enhance the vitamin content in staple crops.
Livestock Breeding: CRISPR allows for the creation of animals resistant to diseases, potentially reducing antibiotic use and improving animal welfare, or enhancing desirable traits like meat quality.
Basic Research:
CRISPR is a tool for biological research, allowing scientists to:
Elucidate Gene Function: By disrupting or altering genes, researchers can investigate their roles in biological pathways and disease development.
Create Disease Models: CRISPR helps create animal models that mimic human genetic diseases, enabling the study of disease progression and testing of new therapies.
B. Ethical and societal implications of designer babies and germline editing
While the potential of CRISPR in somatic cells is supported, editing the human germline raises ethical concerns.
Safety and Unintended Consequences:
Off-target Effects: There is a risk of unintended edits at sites in the genome that are similar to the target sequence. These "off-target effects" could lead to changes, potentially altering gene function or causing new mutations with unknown impacts on health and development.
Mosaicism: When editing occurs in early embryos, not all cells may be successfully edited, resulting in a mosaic individual with a mix of edited and

unedited cells. The impact of mosaicism is not fully understood.

Irreversible Changes: Germline edits are permanent and will be passed down to all future generations. This raises questions about the right to make irreversible changes to the human gene pool without a complete understanding of the long-term consequences.

{Image Suggestion 3: Diagram illustrating potential off-target effects of CRISPR}

A schematic showing how gRNA might bind to unintended sites with partial homology, leading to off-target cleavage. Based on information found in sources like ScienceDirect.com and ResearchGate.

Socioeconomic Disparities and Inequality:

The high cost and expertise needed for germline editing could make it accessible only to the wealthy, potentially increasing socioeconomic disparities. This raises concerns about whether a "genetically enhanced" elite could emerge.

{Graph Suggestion 1: Graph on access to germline editing and socioeconomic factors}

A conceptual graph depicting how factors like cost and expertise might limit accessibility to germline editing, potentially widening health disparities. Derived from discussions in sources like Number Analytics.

Eugenics:

The term "designer baby" evokes the historical shadow of eugenics, the movement that aimed to "improve" the human species through selective breeding. Concerns exist that germline editing, if misused for non-medical enhancements, could lead to a new form of eugenics, where societal pressures might encourage genetic modification to meet arbitrary standards of "desirability".

This could lead to discrimination against individuals who choose not to undergo such procedures or those who possess naturally occurring genetic variations.

Impact on Human Diversity and Disability Rights:

The pursuit of eliminating certain diseases or enhancing traits through germline editing raises questions about its impact on human diversity. Some argue that eliminating conditions like deafness or dwarfism, while potentially beneficial for individuals, could diminish the richness of human genetic variation and the lived experiences of those with disabilities.

Disability advocates voice concerns that widespread germline editing could devalue the lives of individuals with disabilities and reduce societal acceptance of diversity.

Long-term Societal and Cultural Impacts:

Beyond individual safety and equity, germline editing poses broader questions about how such technology might reshape societal norms and values. What constitutes "normal" or "desirable" could shift, leading to new forms of social pressure and potential changes in how we perceive parenthood and human identity.

C. Regulatory landscape

The fast advancement of CRISPR technology has outpaced the development of comprehensive regulatory frameworks in many parts of the world. However, international and national bodies are addressing these issues.

Global Approach to Germline Editing:

Many countries, particularly in Europe, have prohibited human germline editing for reproductive purposes. The Council of Europe's Oviedo Convention calls for a prohibition on altering the human germline.

Other countries, like China, the United Kingdom, and the United States, have more nuanced positions. While they generally prohibit heritable changes,

research involving germline editing for non-reproductive purposes (e.g., in embryos not intended for implantation) may be permitted under strict ethical oversight.

{Report Suggestion 2: Table comparing regulatory stances across different countries}

A table summarizing the legal and policy frameworks regarding human germline editing in key countries (e.g., USA, UK, China, Germany) based on sources like Mary Ann Liebert, Inc., or as referenced in.

Conclusion

Research towards improving the specificity and reducing the off-target effects of the CRISPR-Cas system is developing towards a safe level that will eventually permit clinical applications in human patients. Given the number of countries that are undecided on the issue of human germline editing, a temporary global ban may be appropriate. This could encourage nations to focus on the technology's ethical, social, and evolutionary implications, leading to legislation aligned with their values. If a country supports human germline editing, it should establish a

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CRISPR, gene editing, and the designer baby debate: a comprehensive analysis

Abstract

The advent of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology has revolutionized the field of genome editing, enabling

precise modifications to the genetic material of living organisms. While offering unparalleled potential for treating genetic diseases, enhancing agricultural yields, and advancing basic biological research, CRISPR's application to human germline editing – inheritable modifications – has ignited intense debate surrounding the concept of "designer babies." This article provides a comprehensive overview of CRISPR technology, its diverse applications, and the complex ethical, social, and regulatory landscape surrounding its use, particularly in the context of human germline manipulation. It addresses the scientific capabilities, potential benefits, inherent risks like off-target effects and mosaicism, and the profound societal implications, including concerns about eugenics, equitable access, and impacts on human diversity. Finally, it surveys the current global regulatory environment. It emphasizes the crucial need for continued interdisciplinary dialogue and responsible innovation to harness CRISPR's potential while safeguarding ethical boundaries and societal values.

Keywords

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## Introduction

The ability to alter the genetic code, the fundamental blueprint of life, has long been a dream of scientists and a subject of both fascination and apprehension for society. For decades, gene therapy relied on methods with limited precision and efficiency. However, the discovery and adaptation of the CRISPR-Cas system, a bacterial defense mechanism, have dramatically shifted this landscape, offering unprecedented accuracy, simplicity, and affordability in genome editing. CRISPR-Cas technology, often described as "molecular

scissors," allows scientists to make targeted changes to DNA sequences, opening vast avenues for scientific discovery and therapeutic development. This remarkable technological advancement brings with it a complex set of opportunities and challenges. On one hand, CRISPR holds immense promise for treating a wide array of devastating genetic diseases by correcting the underlying mutations. On the other hand, the possibility of using CRISPR to modify the human germline—changes that would be passed down to future generations—has ignited a global debate about the creation of "designer babies." This term refers to the hypothetical scenario where human embryos are genetically modified to possess specific desired traits, raising profound ethical, social, and even philosophical questions about human identity, diversity, and the boundaries of scientific intervention.

This article will explore the development of CRISPR technology, detailing its mechanisms and contrasting it with previous gene editing tools. It will then cover its applications, from medicine to agriculture, followed by a focus on human germline editing and the "designer baby" concept. It will discuss the ethical concerns, including safety, equity, eugenics, and human diversity. The article will review the global regulatory environment and the path toward responsible technology development and application.

Materials and methods

CRISPR-based gene editing focuses on the targeted cleavage of specific DNA sequences. This section will describe the CRISPR-Cas system's mechanism and compare it to earlier genome editing technologies.

Mechanism of the CRISPR-Cas system

The CRISPR-Cas system comes from a bacterial adaptive immune system designed to protect against viral infections. The system, especially the CRISPR-Cas9 variant, consists of two components:

Guide RNA (gRNA): This engineered RNA molecule features a spacer sequence (~20 nucleotides) that specifically matches the target DNA sequence and a constant scaffold sequence that binds to the Cas9 enzyme. The spacer sequence guides the Cas9 enzyme to the specific location in the genome.
Cas9 Enzyme: This DNA-cutting enzyme (nuclease) acts as molecular scissors. Guided by the gRNA, Cas9 creates a double-strand break (DSB) in the DNA.
The process includes these steps:
Target Recognition: The Cas9 enzyme and gRNA complex scan the host genome for a DNA sequence complementary to its spacer sequence. This recognition requires a Protospacer Adjacent Motif (PAM) (e.g., NGG for Cas9 from Streptococcus pyogenes), which must be present adjacent to the target site for binding and cleavage.
DNA Cleavage: Upon successful target recognition, Cas9 cuts both DNA strands, creating a double-strand break.
DNA Repair and Editing: The cell's natural DNA repair mechanisms then attempt to mend this break. There are two primary pathways:
Non-Homologous End Joining (NHEJ): This error-prone pathway can result in insertions or deletions (indels) at the cut site, commonly used for "knocking out" a gene.
Homology-Directed Repair (HDR): If a DNA template with homology to the cut site is provided, the cell can use this template to repair the break, allowing for the precise insertion of new genetic material or correction of specific mutations.
{Image Suggestion 1: Diagram illustrating the CRISPR-Cas9 mechanism}
A visual representation showing the gRNA guiding Cas9 to the target DNA sequence, the double-strand break, and the two repair pathways (NHEJ and

HDR) with their respective outcomes. Resources like the National Institute of General Medical Sciences (NIGMS) (.gov) and ResearchGate offer examples.

Comparison with previous gene editing technologies

Before CRISPR-Cas systems, Zinc Finger Nucleases (ZFNs) and Transcription Activator-like Effector Nucleases (TALENs) were utilized for targeted genome editing. These earlier technologies also employed engineered nucleases to induce double-strand breaks, but had certain limitations:

Complexity: ZFNs and TALENs require the design and construction of unique proteins for each target DNA sequence, a process that is often complex and time-consuming.

Cost: The engineering of target-specific proteins for ZFNs and TALENs made their application relatively expensive.

Efficiency and Precision: Compared to CRISPR-Cas systems, ZFNs and TALENs could be less efficient and exhibit higher off-target effects.

CRISPR's advantages in ease of design, low cost, and higher efficiency have propelled it to the forefront of genome editing technologies.

{Image Suggestion 2: Graph or table comparing gene editing technologies}

A table or bar graph illustrating the relative ease of use, cost, and efficiency of ZFNs, TALENs, and CRISPR-Cas9 based on information found in sources like the National Institutes of Health (NIH) | (.gov) and ResearchGate.

Results and discussions

CRISPR technology offers a wide range of applications with significant potential for both benefits and risks. This section will explore the applications of CRISPR and then delve into the ethical and societal issues surrounding human germline editing and the concept of "designer babies."

A. Potential benefits of CRISPR technology

CRISPR's precision and versatility have unlocked new possibilities in various fields.

Treating Genetic Diseases:

Somatic Gene Editing: Current clinical applications primarily focus on somatic (non-reproductive) gene editing, aiming to correct disease-causing mutations in differentiated cells of affected individuals. Examples include:

Sickle Cell Anemia and Beta-Thalassemia: Clinical trials are investigating CRISPR-based therapies to address these debilitating blood disorders.

Cystic Fibrosis: Research is underway to correct mutations in the CFTR gene responsible for this severe lung disease.

Huntington's Disease and other Neurodegenerative Disorders: Scientists are exploring CRISPR to target and inactivate genes implicated in these progressive neurological conditions.

Cancer Therapies: CRISPR is being utilized to enhance adoptive cell therapies like CAR-T cell therapy, modifying a patient's immune cells to improve their ability to identify and destroy cancer cells.

{Report Suggestion 1: Table of potential CRISPR gene therapies in clinical trials}

A table summarizing ongoing or recently completed clinical trials using CRISPR for various diseases based on Molecular Cancer and as described by the National Institutes of Health (NIH) | (.gov).

Agricultural Applications: CRISPR is revolutionizing agriculture, enabling the development of crops with enhanced traits and improved livestock.

Crop Improvement: Modifying crops for increased yield, enhanced nutritional content, resistance to pests and diseases, and tolerance to environmental stresses (like drought and salinity) can contribute significantly to global food

security. For instance, CRISPR has been used to engineer disease-resistant wheat or to enhance the vitamin content in staple crops like rice.

Livestock Breeding: CRISPR enables the creation of animals resistant to diseases, potentially reducing reliance on antibiotics and improving animal welfare, or enhancing desirable traits like meat quality.

Basic Research:

CRISPR serves as an invaluable tool for fundamental biological research, allowing scientists to:

Elucidate Gene Function: By precisely disrupting or altering specific genes, researchers can investigate their roles in various biological pathways and disease development.

Create Disease Models: CRISPR facilitates the creation of accurate animal models that mimic human genetic diseases, enabling detailed study of disease progression and testing of new therapeutic strategies.

B. Ethical and societal implications of designer babies and germline editing

While the potential of CRISPR in somatic cells is generally well-received, the prospect of editing the human germline presents profound ethical and societal challenges.

Safety and Unintended Consequences:

Off-target Effects: A primary concern is the risk of unintended genetic modifications at locations in the genome similar to the target site. These "off-target effects" could disrupt essential genes, potentially leading to unforeseen adverse health consequences for the individual and future generations.

Mosaicism: When editing occurs in early embryos, some cells may acquire the desired edit while others do not, resulting in a mosaic individual with a mixture of edited and unedited cells. The implications of mosaicism are currently not

fully understood and could lead to unpredictable outcomes or even failure to treat the targeted disease.

Irreversible Changes: Germline edits are permanent and inheritable, meaning they will be passed down through all subsequent generations. This raises serious questions about the ethical justification of making irreversible alterations to the human gene pool without a complete understanding of the long-term consequences.

{Image Suggestion 3: Diagram illustrating potential off-target effects of CRISPR}

A schematic showing how gRNA might bind to unintended sites with partial homology, leading to off-target cleavage. Based on information found in sources like ScienceDirect.com and ResearchGate.

Socioeconomic Disparities and Inequality:

The high cost and specialized expertise required for germline editing raise concerns about equitable access. This technology could potentially become available only to the wealthy, exacerbating existing socioeconomic disparities and creating a divide between the genetically "enhanced" and the rest of society.

{Graph Suggestion 1: Graph on access to germline editing and socioeconomic factors}

A conceptual graph depicting how factors like cost and expertise might limit accessibility to germline editing, potentially widening health disparities. Derived from discussions in sources like Number Analytics.

Eugenics:

The term "designer baby" carries the historical weight of eugenics, a movement from the early 20th century that aimed to "improve" human populations through selective breeding and coercive measures. Concerns persist that

germline editing, if applied for non-medical enhancements, could pave the way for a new form of eugenics, potentially leading to social stratification based on genetic traits.

This raises fears of devaluing individuals with genetic differences or disabilities, leading to discrimination and potentially a reduction in human genetic diversity.

Impact on Human Diversity and Disability Rights:

The pursuit of eliminating certain diseases or enhancing traits through germline editing raises questions about its potential impact on human diversity. Some argue that eliminating conditions like deafness or dwarfism could diminish the richness of human genetic variation and the unique contributions of individuals with disabilities.

Disability rights advocates are concerned that widespread germline editing could send a message that people with disabilities are inherently less valuable, potentially reducing societal acceptance and inclusion.

Long-term Societal and Cultural Impacts:

Beyond individual safety and equity, germline editing poses broader questions about how such technology might fundamentally reshape societal norms and values. It could alter perceptions of parenthood, family relationships, and human identity, necessitating ongoing ethical and societal reflection.

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CRISPR gene-editing techniques are not new. But ethicists and scientists around the world seem to have uniformly condemned the experiment.

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CRISPR-Cas9 and Designer Babies: The Ethical Debate (Part ...

Undoubtedly, gene editing could potentially eliminate genetic diseases from a family's lineage, but it could also introduce unintended mutations ...

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Can We Create Designer Babies with Gene Editing? - Healthline

U.S. experts currently don't support the practice of creating designer babies via gene editing. However, PGT can identify healthier embryos ...

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Gene-Editing and the Controversial Use of CRISPR

The concept of designer babies has been discussed extensively after a Chinese doctor claimed he helped create two babies with modified genes.

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New Hope Fertility Center

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Designer Babies - New Hope Fertility

CRISPR designer babies are created by modifying DNA fragments to prevent and correct disease-causing genetic errors. CAS9 is a special ...

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MIT Technology Review

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The First Chinese Edited Babies: A Leap of Faith in Science

Using CRISPR technology to immunise the babies against the HIV[2], He Jiankui managed to disable the CCR5 gene that enables the HIV infection (although he ...

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Science | AAAS

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https://www.science.org

Did CRISPR help—or harm—the first-ever gene-edited babies?

Those changes could cause cancer or other problems. He contends that the babies have no such off-target mutations, although some scientists are skeptical of the ...

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Open to Debate

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https://opentodebate.org

Should We Use Gene Editing to Make Better Babies?

CRISPR gene editing can cause unwanted changes in human embryos, study finds · New technologies may have already introduced genetic errors to the human gene pool ...

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American Society for Microbiology

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https://asm.org

The Designer Baby Distraction

One of today's biggest public misconceptions about CRISPR is that designer babies are around the corner. These dystopian fears are not new.

Ask anything

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| 2. | ~~the~~ HIV | Determiner use (a/an/the/this, etc.) | Correctness |