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Medical Miracle or Modern Eugenics? Gene Modification in the 21st Century

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ABSTRACT

The rapid development of gene-editing technologies has introduced new possibilities for preventing disease and enhancing human traits. From TALENs to CRISPR-Cas9, scientific abilities have stretched beyond what was once thought possible. Nevertheless, the emergence of these innovations raised profound ethical concerns about the future of human reproduction and the boundaries of scientific intervention. This paper examines the ethical implications of gene editing by placing it within the historical context of eugenics, a movement that sought to improve human populations through controlled reproduction and selective breeding. By analyzing both early twentieth-century eugenic practices in the United States and Nazi Germany, in addition to various contemporary advancements, this study evaluates whether gene editing represents a medical breakthrough or a modern continuation of selective human engineering. Drawing on the ethical principles of beneficence, nonmaleficence, justice, and autonomy, this paper argues that although gene editing offers significant potential to reduce suffering and eliminate hereditary disease, its application, particularly in germline modification, poses serious risks to social inequality and long-term ethical instability. Ultimately, this paper concludes that gene editing is not yet ethically permissible due to insufficient regulation, limited understanding of long-term consequences, and the potential to deepen existing social and global inequalities.

INTRODUCTION

Few biomedical technologies have generated as much ethical anticipation and controversy as gene editing. The ability to alter the human genome with increasing precision promises unprecedented opportunities for disease prevention and treatment while simultaneously challenging longstanding assumptions about reproduction, disability, human diversity, and the limits of scientific intervention. Advances in genetic technology have fundamentally reshaped the relationship between medicine and human agency, transforming questions that once belonged to philosophy and science fiction into matters of practical scientific possibility. As gene-editing tools become more sophisticated and accessible, it is imperative that society confront difficult questions about who should govern these technologies and what limitations, if any, should be implemented.

The development of CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats-associated protein 9) has accelerated these debates by providing scientists with an efficient and highly precise method of modifying DNA. CRISPR-Cas9, discovered in 2012 by Dr. Jennifer Doudna and Dr. Emmanuelle Charpentier, immediately brought a new vision to the scientific community. Unlike earlier forms of genetic engineering, CRISPR-Cas9 enables targeted alterations to the genome with a level of accuracy that has dramatically expanded the potential of genetic intervention. These capabilities offer extraordinary medical promise, including the possibility of eliminating hereditary diseases before birth and reducing the burden of genetic disorders for future generations. For instance, CRISPR-Cas9 has been used to develop treatments for sickle cell disease, a genetic disorder caused by mutations in the hemoglobin gene. By editing a patient's blood stem cells, researchers can restore healthier blood cell function and reduce the painful complications associated with the disease (Frangoul et al.). At the same time, the ability to modify human genetic traits raises concerns that extend beyond individual medical outcomes. Decisions about which traits to alter inevitably reflect broader assumptions about normality and human value, bringing to light what society considers to be a "good" trait. For example, while using CRISPR-Cas9 to correct a mutation that causes a severe inherited disease may be considered a therapeutic application of gene editing, modifying embryos to influence traits such as height, intelligence, athletic ability, or physical appearance raises a different ethical dilemma. These traits are not simply about preventing suffering but involve subjective judgments about which characteristics are considered desirable or superior. If society begins using genetic technologies to favor certain traits, it could reinforce existing ideas about human "betterment" and recreate patterns similar to devastating historical eugenics movements.

Such historical eugenics movements sought to "improve" the human population through selective reproduction by encouraging the reproduction of those considered genetically desirable while restricting the reproduction of those deemed "unfit." Throughout the late nineteenth and early twentieth centuries, eugenics movements sought to improve human populations through selective reproduction, often relying on scientific rhetoric to justify policies rooted in racism, ableism, and intentional social exclusion. Although contemporary gene-editing technologies differ substantially from historical eugenic programs, the comparison is not entirely dismissible. Both involve judgments about desirable traits and raise questions about what particular characteristics should be valued over others. The relationship between modern gene editing and historical eugenics is therefore neither straightforward nor entirely disconnected. While gene editing is frequently framed as a tool of individual choice and medical advancement, its broader social implications warrant careful ethical examination.

Drawing upon the principles of beneficence, the obligation to promote human well-being; nonmaleficence, the responsibility to avoid causing harm; autonomy, the respect for individuals' right to make informed decisions about their own bodies; and justice, the commitment to fairness and equal access to medical advancements, this paper argues that although gene-editing technologies possess extraordinary potential to alleviate suffering and prevent disease, their widespread implementation cannot yet be ethically justified. Persistent concerns regarding safety, inequality, disability rights, and insufficient

regulatory oversight suggest that existing ethical frameworks remain inadequate to govern technologies that can alter not only individual lives but also those of future generations.

METHODS

This study employed a qualitative literature review to examine the ethical implications of human gene-editing technologies through historical, scientific, and philosophical perspectives. Rather than collecting primary data, the research relied on secondary sources to evaluate whether contemporary gene-editing technologies represent a medical advancement or raise ethical concerns reminiscent of historical eugenics. The literature examined included peer-reviewed journal articles, government and institutional publications, historical analyses, legal documents, and bioethics scholarship.

Sources were identified through searches and conducted between January 2025 and June 2026 using Google Scholar, PubMed, JSTOR, and institutional resources including the National Human Genome Research Institute (NHGRI). Additional sources were identified through citation tracking of frequently referenced publications within genetics, bioethics, disability studies, and reproductive ethics. Search terms included combinations of "CRISPR-Cas9," "human gene editing," "gene editing ethics," "eugenics," "genetic enhancement," "disability ethics," "reproductive autonomy," "justice and gene editing," and gene-editing regulation."

Sources were selected according to three criteria (1) scholarly or institutional credibility, including peer-reviewed journals and publications from recognized scientific or governmental organizations; (2) direct relevance to the ethical, historical, scientific, or regulatory dimensions of human gene editing and (3) contribution to the central research question of whether modern gene-editing technologies represent an ethical medical innovation or a potential continuation of historical patterns of genetic selection and reproductive control. Historical sources predating the development of CRISPR technology were included when necessary to provide context for twentieth-century eugenics, forced sterilization, and reproductive policy.

The selected literature was analyzed thematically by comparing recurring ethical concerns across disciplines, including beneficence, nonmaleficence, autonomy, justice, disability ethics, and global equality. Historical scholarship on American eugenics and Nazi Germany were examined alongside contemporary discussions of CRISPR-Cas9, germline editing, and international regulation to identify both similarities and distinctions between historical reproductive control and modern genetic technologies. Rather than treating gene editing and eugenics as equivalent, the analysis evaluated how historical experiences can inform contemporary ethical governance of emerging biotechnology.

Inclusion Criteria	Exclusion Criteria
Peer-reviewed journal articles	Opinion pieces lacking scholarly or institutional support
Government and institutional publications (e.g., NHGRI, NIH)	Sources focused solely on technical laboratory methods without ethical or societal analysis
Scholarly literature on human gene editing (e.g., CRISPR-Cas9, germline and somatic editing)	Studies involving only plant, animal, or microbial gene editing
Historical analyses of eugenics, reproductive control, and related legal cases	Sources unrelated to human genetics, bioethics, or reproductive medicine
Publications addressing bioethical principles, disability ethics, justice, autonomy, or genetic enhancement	Duplicate publications
LIterature examining regulation, public policy, global access, and social implications of gene editing	Non-English publications
English-language sources, with priority given to recent publications while including seminal historical works when relevant	Sources that did not directly address the research question

Table 1: Summarizes the inclusion and exclusion criteria used during the literature selection process.

THE HISTORICAL FOUNDATIONS OF EUGENICS

To fully understand the ethical implications of modern gene-editing technologies, it is essential to examine the historical foundations of eugenics and how science has been used to justify social control and inequality. The eugenics movement, which gained prominence in the late nineteenth and early twentieth centuries, was rooted in the belief that human populations could be improved through selective reproduction (NHGRI). While it was often presented as a scientific and humanitarian effort aimed at reducing disease and improving overall quality of life, it was deeply influenced by existing social hierarchies. For example, the United States' eugenics movement used intelligence testing and flawed scientific theories about heredity to classify certain groups, including people with disabilities, immigrants, and impoverished communities, as biologically inferior. These classifications were then used to justify discriminatory policies such as forced sterilization, demonstrating how scientific authority could be manipulated to reinforce existing social inequalities. These biases shaped definitions of genetic fitness and desirability, resulting in policies that disproportionately targeted marginalized populations. Such beliefs were not limited to scientific theories but were translated into government policies that directly controlled reproduction. For example, Virginia's 1924 Eugenical Sterilization Act authorized the forced

sterilization of individuals considered "mentally defective." Additionally, according to the National Human Genome Research Institute (NHGRI), American eugenicists' beliefs about who were considered "fit" or "unfit" contributed to the involuntary sterilization of at least 60,000 people across 30 states by the 1970s. These people largely consisted of those with disabilities, African Americans, Latinx communities, Native Americans, and economically disadvantaged individuals. The scale of these practices demonstrates that eugenics operated not as a mere ideology but as a system of institutional power that allowed medical and governmental authorities to regulate the reproductive choices of marginalized populations.

What rendered eugenics particularly dangerous was not the pseudoscientific assumptions upon which it rested, but the institutional legitimacy it acquired. Framed as an objective and evidence-based effort to improve society, eugenics transformed deeply rooted social prejudices into seemingly rational public policy. This is evident once again in the Virginia Eugenical Sterilization Act. The concepts in this policy were later upheld in *Buck v. Bell* (1927), when the Supreme Court ruled that forced sterilization did not violate constitutional rights. As a result, more than 3,000 men in Virginia underwent forced sterilization through vasectomy, while estimates suggest that over 60,000 people were sterilized across the United States as eugenic practices expanded (Moore et al.). Scientific language provided moral and political justification for discrimination, allowing racial hierarchies, ableist assumptions, and class-based biases to be recast as biological truths rather than social constructions. As a result, the eugenics movement demonstrates how scientific authority can become ethically hazardous when it is used to reinforce existing social inequalities rather than challenge them.

Margaret Sanger is a particularly notable figure in this context, as her contributions to reproductive rights are both significant and ethically complex. Sanger was instrumental in expanding access to birth control and advocating for women's reproductive autonomy, most notably through the establishment of the first birth control clinic in the United States (1916). Her work played a crucial role in shifting public attitudes toward contraception and ultimately contributed to the development of modern reproductive healthcare systems. In 1921, Sanger founded the American Birth Control League (ABCL), the first organization in the United States dedicated to advocating for legalized contraception, women's reproductive rights, and reproductive healthcare; it later became the foundation for the Planned Parenthood Federation of America in 1942 (Moses). However, her association with eugenic ideas reveals the tension between progressive reform and discriminatory ideology. Sanger supported certain aspects of eugenic thought, particularly the belief that limiting reproduction among those deemed unfit could improve societal well-being (Michals). This contradiction demonstrates the complexity of separating scientific and social progress from the values embedded within them.

While Sanger's advocacy expanded reproductive autonomy for many women, the incorporation of eugenic principles reflected a broader societal tendency to categorize different lives with different levels of desirability. This same idea used to promote individual choice could also be applied to justify external control over reproduction, revealing how medical and scientific movements can unintentionally reinforce inequality when they rely on assumptions about which human traits are considered preferable. This duality is especially relevant to modern gene-editing debates.

The dangers of eugenic ideology became most evident in its extreme application under Nazi Germany, where the concept of genetic improvement was used to justify widespread human rights violations. Under Adolf Hitler's regime, eugenics was transformed into a system of state-sponsored policies designed to create a racially pure population through forced sterilization, euthanasia, and ultimately genocide. The 1933 Law for the Prevention of Hereditary Diseases Offspring mandated the sterilization of hundreds of thousands of individuals who were considered genetically inferior, including those with disabilities and mental illnesses. This policy expanded into programs such as Aktion T4, which authorized the systematic killing of disabled individuals, and culminated in the Holocaust, where millions of people were exterminated based on racial and ideological criteria (Bennhold). These events demonstrate how scientific authority can be manipulated to justify violence and oppression when combined with discriminatory values. The historical legacy of eugenics serves not only as a record of past atrocities but as a warning that scientific advancement without ethical restraint can lead to devastating consequences.

It is important to recognize that contemporary medical genetics operates within a fundamentally different ethical framework than historical eugenic movements. Unlike eugenic programs of the twentieth century, which relied on coercion, discrimination, and state-enforced reproductive control, modern clinical genetics is guided by principles of informed consent, patient autonomy, beneficence, and respect for human dignity. Advances in genetic medicine have largely focused on reducing suffering and expanding individual choice rather than defining which lives are more or less valuable. However, the historical legacy of eugenics remains relevant because it demonstrates how scientific knowledge can be misused when ethical safeguards fail. Therefore, the comparison between eugenics and modern gene editing should not be understood as an assertion of equivalence, but rather as a cautionary examination of how emerging technologies must be governed responsibly.

EUGENICS IN 20TH-CENTURY AMERICA

Although eugenics is often associated with Nazi Germany, similar ideologies were deeply embedded in American public policy throughout the twentieth century, particularly in the area of reproductive control. As demonstrated through figures such as Margaret Sanger, discussions surrounding reproduction and public health often existed at the intersection of individual autonomy and broader social ideas about which populations should reproduce. Programs designed to limit the reproduction of individuals deemed unfit were implemented on the grounds that they would improve public health and reduce economic burdens on society. This disproportionately targeted marginalized populations such as poor individuals, people of color, and those with disabilities. One of the most revealing examples of this practice is the case of Relf v. Weinberger, which exposed the coercive sterilization of two young African American sisters, Minnie and Mary Relf. In 1973, the Relf sisters underwent sterilization after their illiterate mother was allegedly deceived into signing a consent form she could neither read nor fully understand (Baker). The consequences of this procedure extended far beyond the immediate violation of consent, as the sterilization permanently altered the Relf sisters' reproductive futures and denied them the ability to make

decisions about parenthood on their own terms. The psychological and emotional impact of having their autonomy taken away without informed consent reflected the lasting harm caused when medical institutions prioritize social assumptions over individual rights.

Although the procedure was carried out through a federally funded family planning program rather than under a state sterilization statute, the Relf sisters' case reveals that reproductive control could continue even after explicit eugenic policies declined. The significance of the case lies not only in the failure of informed consent but in how it exposed the unequal distribution of reproductive power. When institutions possess the authority to determine who is capable of making reproductive decisions for themselves, consent becomes little more than a procedural formality. The Relf sisters' sterilization illustrates how social and economic vulnerability could be used to limit reproductive autonomy, allowing eugenic ideas about controlling reproduction to persist even when the language of heredity and genetic fitness was no longer openly used.

More importantly, the Relf case highlights the intersection of race, poverty, and inequality in shaping access to reproductive autonomy. The sisters were not targeted in isolation; they belonged to a poor Black family that depended on government-funded services, placing them within a population that had historically been viewed by policymakers and medical authorities as less deserving of reproductive freedom. As Linda Villarosa argues, American reproductive policies have long reflected assumptions that certain groups are less fit for parenthood than others, even when those judgments are framed in economic or social rather than biological terms. The ethical significance of the Relf sisters' sterilization, therefore, extends beyond individual wrongdoing. It highlights fundamental questions about justice and equality, particularly whether similar actions would ever have been imposed upon affluent families with greater educational resources, legal protections, and social influence. By revealing how reproductive restrictions disproportionately affected marginalized communities, the Relf case demonstrates that eugenics survived not merely as an ideology but as a system of power that continued to regulate whose reproduction was valued and whose was subject to institutional control.

While the Relf sisters' case reveals how reproductive control operated through government programs and the manipulation of consent, similar patterns of reproductive regulation also emerged within medical institutions themselves. The shift from explicit sterilization policies to more concealed forms of intervention did not eliminate eugenic logic; instead, it transformed the way reproductive control was justified and carried out. Rather than openly determining who should or should not reproduce, medical authorities increasingly exercised control through clinical practices that framed reproductive removal as necessary treatment.

The "Mississippi appendectomy," a term used to describe the non-consensual sterilization of Black women through medical procedures, illustrates the continuation of reproductive control by demonstrating how racialized assumptions about reproduction could persist through the language of medicine rather than through formal eugenic policy. Rather than relying on sterilization statutes or explicit claims about

hereditary fitness, physicians often framed irreversible reproductive procedures as routine medical treatment, obscuring their true consequences from patients.

The experience of civil rights activist Fannie Lou Hamer illustrates this dynamic. In 1961, Hamer entered a Mississippi hospital for treatment related to a uterine tumor and underwent a hysterectomy without her knowledge or consent (Lasky). At the time, she was a poor Black woman living in the segregated South, where racial discrimination and unequal access to medical care shaped many healthcare experiences. Although the procedure was presented as a medical intervention, it permanently ended her ability to have children without her informed consent. This case reflects a larger pattern in which Black women's reproductive autonomy was disregarded, and medical authority was used to make decisions about their bodies without their participation. It became one of the most widely recognized examples of reproductive injustice because it revealed how institutional power could permanently alter a woman's reproductive future without meaningful informed consent. The ethical significance of this case extends beyond the absence of informed consent. It reveals how medical expertise can become a mechanism of power when patients are denied the information necessary to understand what is being done to their bodies. By disguising sterilization as therapeutic care, physicians transformed reproductive capacity into something that could be managed, removed, or controlled without a patient's knowledge. The Mississippi appendectomy, therefore, exposes a deeper problem within the history of reproductive medicine: the ability of institutional authority to redefine coercion as treatment and reproductive deprivation as medical necessity.

History suggests that these procedures were not isolated abuses but patterns within a larger system that disproportionately targeted marginalized populations. The Mississippi appendectomy existed within a broader American system of eugenic sterilization that was legally supported across the country. Beginning with Indiana's sterilization law in 1907, thirty-one states eventually adopted policies that allowed the forced sterilization of individuals considered "socially undesirable," including people labeled as poor, disabled, criminal, or "feebleminded". These policies contributed to the sterilization of more than 60,000 individuals in the United States between the 1920s and 1970s, demonstrating that reproductive control was not the result of isolated medical misconduct but part of an institutional framework that authorized the regulation of marginalized populations' ability to reproduce (Lasky).

Coerced sterilizations of Black women occurred within a social environment shaped by persistent fears about poverty, dependency, and the reproduction of communities deemed undesirable by those in positions of power (Roberts). The scale of these practices is evident in states such as North Carolina, where approximately 7,600 individuals were involuntarily sterilized between 1929 and 1974. Women and people of color represented a disproportionate number of those affected (Lasky). These patterns demonstrate that sterilization policies often operated through overlapping systems of racial and economic inequality rather than through medical necessity alone. The issue was not simply racial prejudice by individual physicians but a widespread institutional belief that certain populations required reproductive oversight. This pattern aligns with what can be described as "sterilization racism," in which reproductive interventions were unfairly imposed upon women of color through practices justified as public welfare,

social responsibility, or medical care (Volscho). Examining the Mississippi appendectomy as an example of this broader system of sterilization racism reveals why the case remains so important to discussions of modern bioethics. It demonstrates that reproductive injustice does not always appear in the form of explicit laws or public policies; it can also emerge through clinical encounters in which unequal power, restricted information, and racialized assumptions undermine genuine autonomy. The lasting significance of the Mississippi appendectomy lies in its challenge to the belief that medical authority is inherently benevolent. Instead, it serves as a reminder that ethical healthcare depends not only on technical competence but also on protecting the patient's right to understand, refuse, and ultimately control decisions about their own reproductive future.

THE RISE OF GENE EDITING TECHNOLOGIES

The development of gene-editing technologies, particularly CRISPR-Cas9, represents one of the most significant scientific breakthroughs of the twenty-first century, fundamentally altering the possibilities of modern medicine and biological research. Unlike earlier genetic engineering techniques, which were expensive, time-consuming, and imprecise, CRISPR-Cas9 offers a relatively efficient, cost-effective, and highly targeted method of modifying DNA. The system originates from a natural defense mechanism found in bacteria, which use clustered regularly interspaced palindromic repeats to identify and neutralize viral DNA. Scientists have adapted this system into a powerful tool for locating specific genetic sequences within an organism and introducing precise modifications. This process involves a guide RNA molecule that directs the Cas9 enzyme to a designated genomic location, where it creates a DNA break. Once this break occurs, the cell's natural repair mechanisms are activated, allowing scientists to either disable a gene or insert new genetic material (Roberts).

What makes CRISPR-Cas9 particularly transformative is not only its precision but its accessibility. Compared to earlier gene-editing technologies such as Zinc Finger Nucleases and TALENs, CRISPR-Cas9 is widely regarded as significantly cheaper and faster to design and implement. This is largely because it relies on simple guide RNA redesign rather than custom protein engineering, lowering both cost and technical barriers to use. This democratization of genetic technology has accelerated scientific discovery, but it has also heightened the urgency of addressing ethical concerns. As more researchers gain access to these tools, the potential for misuse or premature application increases, especially in the absence of consistent global regulation.

A key distinction within gene editing lies between somatic and germline modifications, which differ significantly in their ethical implications. Somatic editing targets non-reproductive cells and affects only the individual receiving treatment, making it generally more ethically acceptable because it focuses on treating existing medical conditions without affecting future generations. Germline editing, on the other hand, involves altering the DNA of embryos or reproductive cells, making the changes heritable and passed down to future generations. This distinction is critical because germline editing extends the consequences of genetic intervention beyond a single individual, transforming reproduction into a form of

biological engineering. While the potential to eliminate inherited diseases is significant, the ability to shape future generations raises complex ethical concerns related to consent, identity, and the long-term impact on human diversity.

CONTEMPORARY ETHICAL DILEMMAS

Although modern gene-editing technologies differ significantly from the coercive reproductive practices of the past, they raise many of the same fundamental ethical questions surrounding power, responsibility, and the boundaries of human intervention. The ability to directly alter the human genome has transformed medicine by creating possibilities for disease prevention and treatment, but it has also introduced new concerns about consent, regulation, and the potential misuse of scientific advancement. The potential of gene editing is not purely theoretical; CRISPR/Cas9 has already demonstrated the ability to correct genetic mutations and restore cellular function in experimental models. Researchers have successfully used CRISPR/Cas9 to correct the mutation responsible for cystic fibrosis in patient-derived intestinal stem cells, restoring normal CFTR function. Additional studies have explored its potential applications in conditions such as Duchenne muscular dystrophy, sickle cell disease, and HIV treatment, demonstrating that gene editing may become a powerful therapeutic tool for addressing previously difficult-to-treat genetic disorders (Redman et al.). However, the same ability to permanently alter genetic material that makes CRISPR-Cas9 promising also creates ethical concerns regarding safety, unintended consequences, and the boundaries of human intervention.

The ethical challenges associated with gene editing became particularly noticeable in 2018 with the case of He Jiankui, a Chinese scientist who announced the birth of the first genetically edited human embryos. His experiment, which involved germline gene editing (meaning the genetic changes would be heritable and passed on to future generations), aimed to make twin girls resistant to HIV by modifying a specific gene, but it was widely condemned due to its lack of transparency, insufficient ethical oversight, and potential risks to the children involved. Specifically, Jiankui used CRISPR-Cas9 to edit the CCR5 gene, which is involved in HIV entry into human cells. However, scientists criticized the experiment because the edits created unintended genetic changes, such as mosaicism (where different cells in the same individual carried different genetic edits) and small insertions or deletions (indels) at the target site, and because the long-term effects of altering embryos were unknown. His actions violated fundamental principles of research ethics, including informed consent and proper review processes, as participants were not fully aware of the risks, and ethical approval procedures were bypassed or falsified (Corcoran). His subsequent sentencing further demonstrated the seriousness of these violations. In 2019, Jiankui was convicted of “illegal medical practice” by a Chinese court and sentenced to three years in prison, along with a fine and a lifetime ban from conducting reproductive medical research. The legal consequences of his actions underscored the need for stronger global regulation by showing that advances in biotechnology must remain subject to ethical oversight, informed consent requirements, and accountability mechanisms.

Beyond the immediate ethical violations, this case illustrates a broader issue in modern science: the growing gap between technological capability and ethical governance. Scientific innovations often advance more rapidly than the systems designed to regulate them, creating situations in which new technologies are used before their consequences are fully understood. In the context of gene editing, this gap is particularly concerning because the stakes are incredibly high. The He Jiankui case exposed a structural problem within contemporary biotechnology: the pace of scientific innovation increasingly exceeds the capacity of ethical and regulatory institutions to govern it. The controversy, therefore, reflected not merely individual misconduct but a broader tension between technological possibility and collective oversight.

The ethical concerns surrounding gene editing extend beyond questions of safety and regulation to deeper issues of equality and social responsibility. While gene-editing technologies have the potential to eliminate devastating genetic diseases, their future use raises concerns about who will have access to these treatments and how society will define acceptable forms of genetic modification. If such technologies become available primarily to wealthy individuals or are used to enhance traits rather than treat illness, they could reinforce existing social inequalities and create new forms of genetic discrimination. This concern reflects historical patterns in which scientific advancements were sometimes used to justify judgments about whose lives were considered more valuable or desirable. Although contemporary gene editing is not inherently a continuation of eugenics, its application requires careful ethical consideration to ensure that it does not reproduce similar patterns of exclusion and inequality under a new scientific framework.

Ultimately, the debate surrounding gene editing is not simply about whether humans should possess the ability to modify life, but about how that ability should be governed. The history of reproductive control demonstrates the consequences of allowing scientific authority to operate without sufficient accountability, particularly when vulnerable populations are affected. The case of He Jiankui serves as a modern example of the importance of ethical oversight, informed consent, and responsible innovation. As gene-editing technologies continue to develop, society must confront the challenge of balancing scientific progress with protections that preserve human dignity, autonomy, and justice.

CLASSICAL ETHICAL FRAMEWORKS: UTILITARIANISM AND DEONTOLOGY

In addition to the core principles of beneficence, nonmaleficence, autonomy, and justice, gene editing can also be examined through broader philosophical perspectives such as utilitarianism and deontology. Although both frameworks seek to guide ethical decision-making, they often reach different conclusions because they evaluate morality according to different standards. This distinction becomes particularly significant when comparing therapeutic gene editing, which aims to prevent or treat disease, with enhancement applications designed to improve traits such as intelligence, athletic ability, or physical appearance.

From a utilitarian perspective, the ethical acceptability of gene editing depends primarily on its consequences. If genetic intervention reduces widespread suffering and produces the greatest overall benefit for society, it may be considered morally justified. This reasoning provides strong support for therapeutic applications that prevent severe hereditary diseases, as eliminating genetic disorders could improve quality of life for both individuals and future generations. However, utilitarianism could also be used to justify certain forms of genetic enhancement if they are believed to increase overall societal well-being. Such reasoning raises important ethical concerns regarding whose interests are prioritized and whether the pursuit of collective benefit could come at the expense of individual rights or reinforce existing social inequalities.

In contrast, a deontological perspective evaluates gene editing according to moral duties and respect for individual rights rather than its outcomes. From this viewpoint, therapeutic gene editing may be ethically permissible when its primary purpose is to fulfill the moral obligation to prevent suffering and respect the dignity of patients. However, deontology is generally more skeptical of enhancement applications because intentionally selecting or designing desirable traits risks treating future children as objects to be optimized rather than individuals with inherent moral worth. Even if enhancement produced positive social outcomes, a deontologist may argue that altering the genetic characteristics of future generations for non-medical purposes violates fundamental ethical duties by reducing human life to a means of achieving preferred outcomes.

Taken together, these perspectives demonstrate both areas of convergence and conflict. Utilitarianism and deontology generally converge in supporting carefully regulated therapeutic applications intended to prevent serious disease, although they justify this conclusion for different reasons: utilitarianism emphasizes reducing suffering and maximizing overall well-being, whereas deontology emphasizes moral duties toward individual patients and respect for human dignity. Their disagreement becomes much more pronounced when gene editing shifts from therapy to enhancement. While utilitarianism may permit enhancement if it produces sufficient societal benefits, deontology raises deeper concerns about the morality of designing future generations according to subjective ideals of human improvement. These contrasting perspectives illustrate that the ethical acceptability of gene editing depends not only on whether the technology works, but also on the moral principles used to evaluate its purpose.

DISABILITY ETHICS AND THE DEFINITION OF "NORMAL"

The ethical implications of gene editing extend far beyond medical considerations and into deeper questions about identity, diversity, and the meaning of human variation. While utilitarianism evaluates gene editing according to its consequences and deontology according to moral duties and individual rights, disability ethics challenges a more fundamental assumption shared by both frameworks: that disability is necessarily a condition to be prevented or corrected. Rather than asking whether genetic intervention is morally justified, disability ethics first asks whether society has correctly defined the problem it seeks to solve. This shift in perspective transforms the ethical debate from one focused solely on the permissibility of gene editing to one that examines the values underlying decisions about which

forms of human variation should continue to exist. While gene editing is often presented as a tool to reduce suffering by preventing genetic conditions, this framing rests on the underlying assumption that certain traits are inherently undesirable and should be eliminated. Disability advocates challenge this assumption by arguing that disability is not defined solely by biological differences, but also by the social, physical, and institutional environments in which individuals live. The social model of disability, which has become influential within disability studies, argues that many limitations experienced by disabled individuals are created not by the impairment itself but by barriers within society. For example, a person who uses a wheelchair may not experience exclusion because of their inability to walk, but because buildings, transportation systems, and public spaces are often designed without accessibility in mind. A staircase without an alternative ramp, nearby elevators, or an inaccessible educational environment transforms a physical difference into a social barrier. From this perspective, the ethical response to disability should not only involve preventing or correcting biological differences but also addressing the societal structures that prevent individuals from fully participating.

This distinction is central to debates surrounding gene editing because the technology has the potential to shift attention away from inclusion and toward elimination. If certain traits associated with disability are increasingly viewed as problems that should be prevented before birth, society may unintentionally reinforce the idea that individuals who possess those traits are less valuable or that their lives are inherently limited. This concern reflects broader historical patterns in which scientific and medical institutions have defined certain bodies and abilities as more desirable than others. The history of eugenics demonstrates the danger of allowing ideas about "improvement" or "normality" to determine whose lives are valued. Although modern gene editing differs from historical eugenic practices because it is generally based on individual choice rather than state-enforced control, both raise questions about who defines which human characteristics should exist and which should disappear.

These concerns become particularly significant when examining conditions such as Down syndrome and autism, which are frequently discussed in relation to prenatal screening and potential genetic intervention. While these conditions can involve medical challenges, this doesn't diminish the value of their lives. Many individuals with Down syndrome live meaningful lives, develop strong social connections, and contribute greatly to their families and communities. Similarly, many members of the autism community have emphasized the concept of neurodiversity, arguing that differences in communication, cognition, and sensory experiences should not automatically be viewed as defects requiring elimination. The neurodiversity movement challenges the assumption that there is one ideal form of human cognition and instead argues that variation is a natural part of humanity. When gene editing is used to prevent these conditions, it raises a difficult ethical question: is medicine reducing suffering, or is it reinforcing a social definition of which types of lives are considered acceptable? This critique exposes an important limitation of both utilitarian and deontological reasoning. Although these frameworks differ in how they justify ethical decisions, they often begin from the same premise—that preventing disability is inherently beneficial. Utilitarianism may support genetic intervention because it reduces suffering and maximizes overall well-being, while deontology may defend it as part of a moral duty to prevent harm and promote health. Disability ethics challenges that shared assumption. If disability is understood not only as a

biological condition but also as the product of inaccessible environments and social exclusion, then eliminating disability through genetic intervention is not necessarily the only—or even the most ethical—response. The central question therefore shifts from whether gene editing reduces suffering to whether society has mistaken social disadvantage for biological deficiency.

The ethical tension becomes especially complex because there is no simple boundary between preventing harm and eliminating difference. There is widespread agreement that preventing conditions associated with severe pain, early death, or extreme medical suffering may represent a legitimate goal of medicine. However, the ethical debate becomes more complicated when genetic technologies are applied to traits that exist along a spectrum of human experience. For example, deafness is often understood by medicine as a condition that can be corrected through hearing technologies or genetic intervention. However, many members of the Deaf community view deafness not as a deficiency but as a cultural identity connected to American Sign Language, shared experiences, and a distinct community. The Deaf community illustrates this tension particularly well. From a utilitarian perspective, preventing deafness may appear ethically desirable because it expands opportunities for communication and increases overall well-being. A deontological perspective may likewise defend intervention if it fulfills a moral duty to prevent impairment. Disability ethics, however, challenges the assumption that deafness should be understood primarily as a harm. For many members of the Deaf community, deafness represents not the absence of an ability but the presence of a distinct language, culture, and identity. Consequently, the ethical disagreement is not simply about whether gene editing should be used, but about whose understanding of disability should define the goals of medicine itself.

The concern is that the expansion of gene editing could gradually redefine more characteristics as undesirable. The National Human Genome Research Institute has noted that advances in genomic screening and technologies, such as polygenic risk scores, have raised concerns among ethicists that genetic information could be used in ways reminiscent of historical attempts to classify and eliminate certain human traits (NHGRI). This does not mean that all uses of gene editing are inherently eugenic; rather, it demonstrates why ethical oversight is necessary to ensure that genetic technologies are used to expand human well-being rather than reinforce narrow definitions of normality.

Ultimately, the debate over disability and gene editing challenges society to reconsider the relationship between medicine and human worth. If technological advancement enables the elimination of certain traits, there is a risk that disability and human variation will increasingly be viewed as problems to be solved rather than experiences to be understood and accommodated. The central ethical question is therefore not simply whether humanity should possess the ability to alter the genome, but how that ability should be used. A future shaped by gene editing could either promote greater health and opportunity or reinforce existing assumptions about which lives are more valuable. Ultimately, disability ethics broadens the ethical conversation by demonstrating that debates over gene editing cannot be resolved solely by weighing consequences or appealing to moral duties. Ethical evaluation also depends upon how society defines health, normality, and human flourishing. While utilitarianism seeks to maximize well-being and deontology emphasizes respect for persons, disability ethics reminds us that well-being cannot be

measured without first considering the perspectives of those most directly affected. Together, these perspectives suggest that the central challenge of gene editing is not only determining what science should permit, but also deciding who has the authority to define which forms of human life require improvement and which deserve acceptance.

JUSTICE, INEQUALITY, AND GLOBAL ACCESS

Even if gene editing eventually proves safe and effective, its benefits are unlikely to be distributed equally. This makes questions of access inseparable from ethical questions, particularly in a global context where disparities in wealth, healthcare infrastructure, and scientific resources are already deeply entrenched. The development of gene-editing technologies introduces the possibility that the ability to improve or prevent certain biological conditions may become another resource determined by socioeconomic status. The high cost of related reproductive technologies, such as in vitro fertilization, which costs approximately $20,000–$25,000 per treatment cycle in the United States before additional expenses associated with genetic testing or modification, demonstrates how emerging biomedical innovations often remain inaccessible to many populations (Peipert et al.). If gene editing follows a similar pattern, access may become concentrated among wealthy individuals and nations, creating a system in which technological advancement benefits those who are already socially and economically privileged. Rather than eliminating inequality, gene editing could risk transforming existing disparities into biological ones.

Within individual societies, this disparity may contribute to the emergence of a genetically advantaged class, in which access to enhanced health, disease prevention, or other desirable traits becomes increasingly tied to financial resources. Over time, these technologies may be associated with educational, professional, and social success. This raises significant concerns about fairness and social mobility, as individuals without access to these interventions may face disadvantages that are no longer solely social or economic but also biological. The result could be a new dimension to global inequality in which opportunities are shaped not only by factors such as income and education but also by who has the ability to alter or optimize their genetic characteristics.

On a global scale, the ethical implications are even more pronounced. Countries with advanced biotechnology sectors, such as the United States and China, possess the scientific infrastructure and financial resources necessary to develop and implement gene-editing technologies, while many in the periphery lack access to basic healthcare services. This creates a troubling disconnect between where medical needs are greatest and where technological benefits are most available. Diseases such as HIV, malaria, and certain genetic blood disorders disproportionately affect populations in lower-income regions, yet these communities may be among the least likely to benefit from emerging genetic treatments. Without intentional efforts to expand accessibility, scientific progress may reinforce global health inequalities by allowing wealthy nations to extend their medical advantages while leaving vulnerable populations behind.

This disparity also raises broader questions about the ethical responsibility of wealthier nations, biotechnology companies, and the scientific community. If gene editing has the potential to reduce suffering on a global scale, does there exist a moral obligation to ensure that its benefits are distributed more equitably? Or will these technologies primarily follow existing market structures, where access is determined by financial ability rather than medical necessity? These questions reveal the limitations of relying solely on economic incentives to drive biomedical innovation. The ethical challenge of gene editing is therefore not only determining whether humanity should possess the ability to alter the genome, but also ensuring that such power does not deepen existing divisions. Without careful attention to this, gene editing may become less of a tool for improving human health and more of a mechanism that reinforces the very inequalities it has the potential to overcome.

COUNTERARGUMENTS AND THE PROMISE OF GENETIC INTERVENTION

Despite the significant ethical concerns surrounding gene editing, many scholars argue that restricting its development may itself be ethically problematic. Preventing serious genetic diseases through germline intervention represents a continuation of medicine's longstanding commitment to reducing human suffering. Conditions such as Huntington's disease, Tay-Sachs disease, and certain hereditary cancers can impose profound physical, emotional, and financial burdens on individuals and families. If safe and effective genetic interventions become available, some ethicists contend that refusing to use them could deny future generations the opportunity to avoid preventable suffering.

Supporters of gene editing also emphasize the distinction between modern genetic technologies and historical eugenics practices. Unlike twentieth-century eugenic programs, which relied on coercion and control, contemporary gene editing is often framed as a matter of individual choice and a promoter of reproductive autonomy. Under this view, parents are not attempting to improve society through selective reproduction but rather seeking to promote the health and well-being of their children. Advocates, therefore, argue that comparisons to eugenics risk obscuring important differences in ethical intent, motivation, and consent.

Furthermore, some scholars suggest that concerns about inequality should be weighed alongside, rather than considered separately from, the technology’s therapeutic potential. Medical innovations have historically been expensive and difficult to obtain, but some have become more accessible over time. While unequal access remains a significant ethical concern requiring careful policy consideration, advocates argue that it should be addressed through equitable regulation and distribution strategies rather than through the complete rejection of genetic intervention.

REGULATION OF FUTURE GENE EDITING

The future of gene editing will depend heavily on the development of comprehensive regulatory frameworks that balance scientific innovation with ethical responsibility. At present, the global landscape of gene-editing regulation is highly fragmented, with countries adopting diverse approaches shaped by their legal systems, cultural values, and scientific priorities. Some nations have implemented strict prohibitions on germline editing, while others have more permissive policies that allow for limited research or clinical application. This inconsistency creates significant challenges, as differences in oversight may encourage researchers to pursue genetic interventions in jurisdictions with fewer restrictions, potentially increasing the risk of unethical practices and complicating efforts to establish shared international standards.

International organizations have begun addressing these challenges by developing ethical guidance for the responsible governance of human genome editing. The World Health Organization (WHO) established an Expert Advisory Committee on Developing Global Standards for the Governance and Oversight of Human Genome Editing, emphasizing the importance of transparency, safety, accountability, and international cooperation. Similarly, UNESCO has highlighted the ethical importance of protecting human dignity, promoting equity, and preventing discrimination in the application of genetic technologies. However, these recommendations are not legally binding. This means their effectiveness depends on individual nations' willingness to implement and enforce them, bringing to light potential varieties in action as nations prioritize their own goals and agendas. As a result, significant challenges remain in creating consistent global standards for regulating technologies with implications that extend across generations.

The case of He Jiankui illustrates the consequences of inadequate regulation, as his experiment was conducted in an environment where oversight mechanisms were insufficient to prevent ethical violations. His actions not only raised concerns about the safety of gene editing but also demonstrated how scientific ambition can outpace ethical consideration when oversight mechanisms are insufficient or inconsistently enforced. This highlights the need for stronger international cooperation in regulating gene-editing technologies, as the global nature of scientific research means that actions taken in one country can have far-reaching implications for others. Without coordinated efforts, it becomes difficult to enforce ethical standards or prevent the misuse of powerful technologies.

Effective regulation must address multiple dimensions of gene editing, including safety, consent, access, and long-term societal impact. This involves establishing rigorous standards for clinical trials, ensuring that participants are fully informed of potential risks. In addition to formal regulations, there is a need for broader public engagement, as decisions about the use of gene editing should not be made solely by scientists or policymakers. Public understanding and participation are essential for ensuring that these choices reflect societal values and ethical priorities rather than purely technical or economic considerations.

Looking toward the future, the challenge is not simply to control gene editing, but to guide its development. This requires a proactive approach that anticipates potential risks and addresses them before they become widespread. It also requires a willingness to set limits, even in the face of significant scientific potential, in order to prevent harm and protect vulnerable populations. Ultimately, the regulation of gene editing will play a decisive role in determining whether it becomes a tool for improving human well-being or a source of new ethical and social challenges.

CONCLUSION

Ultimately, the ethical challenge posed by gene editing extends far beyond the question of scientific capability. Humanity now possesses technologies that may allow it to alter the genetic characteristics of future generations, but the existence of this capability does not justify its unlimited use. The history of eugenics shows the dangers of relying on assumptions about human value and social worth to influence scientific decision-making. Although modern gene editing is motivated by different goals and ethical frameworks, it nevertheless raises similar concerns regarding who determines which traits are desirable.

At present, uncertainties surrounding long-term safety, equitable access, and international regulation make widespread germline gene editing difficult to ethically justify under current conditions, though future developments may alter this assessment. However, this conclusion should not be understood as a permanent rejection of the technology or a universal ethical consensus. Future developments in scientific understanding, safety measures, and governance frameworks may alter the ethical assessment of certain applications, particularly those focused on preventing severe hereditary diseases. Until such safeguards are sufficiently established, a cautious and evidence-based approach remains necessary. The decisions made during the early stages of gene-editing technologies may influence not only the future of medicine but also broader societal understandings of diversity, equality, and human dignity.

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