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Article

Codes of Tomorrow: Genomic Sequencing Futures in Mexico of 2035

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Abstract

This article explores the future of genomics in Mexico by 2030. It addresses the research questions: what are the potential futures of genomic sequencing in Mexico towards 2035? and what is the impact of this technology for healthcare, agriculture and biodiversity conservation? Previous studies have highlighted genomic sequencing on a global scale. This research fills a gap, by focusing on the local ethical and regulatory challenges in Mexico. Foresight methods like Futures Triangle, 2x2 Matrix, Causal Layered Analysis, coupled with Horizon Scanning and expert interviews, led to four scenarios centered on technology costs and ethical challenges and key uncertainties. Findings emphasize foresight's strategic value in complex fields such as genomic sequencing, contributes to anticipating rapid genomic advances that could present both challenges and opportunities and it enhances strategic pathways for navigating future diverse scenarios.

Keywords

Foresight, Genomic Sequencing, Genomics Governance

Introduction

This research aimed to carry out one of the first investigations applied to the future of genomic sequencing, focusing the lens on Mexico. Although current literature provides a global outlook, there is a gap in applying strategic foresight in Mexico for assessing future implications of the human genome technology advancements.

In the context of accelerated change, foresight techniques are essential to anticipate future risks and opportunities in various industries and sectors of public life. For example, in the field of medicine, a sector that will be highly disrupted due to the impact of new technologies, some authors have conducted prospective analyses to anticipate the impacts of virtual reality and health technologies on healthcare systems (O'Neil, 2022; Gauthier & Wac, 2015), or to explore the futures of healthcare after the 2020 pandemic (Boonmavichit & Hobbs, 2023).

In the field of genomic sciences, authors such as Damrongchai, Johnston, and Tegart (2010) highlight the importance of foresight applied to genomic sciences to understand the complexity of the potential impacts on human healthcare. Dandara et al. (2012) stressed the need for more research on how personalized information in genomics will affect healthcare systems. Similarly, Fatehi (2021) explores how future disparities in capitalist societies may heighten due to future developments in genome science. In the case of genome research, the author suggests that recent medical, biological, and technological developments are already upgrading the human body through advancements such as organ transplants and genetic manipulation to eliminate various defects or create 'superhumans.'

At the turn of the millennium, prospective research in genomic sequencing that resembles the present one in its objectives was conducted by Justman, Bezold, and Rowley (2002). Integrating forecasts and key factors shaping

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genomics at the time of publication, the authors developed four alternative scenarios to explore the broad interactions between genomics and its applications in the then-futuristic society projected for 2015. Likewise, through a horizon scanning technique, the foresight report Genomics Beyond Health (2022) explores how genomics will affect human in the future and, particularly, how the genome can influence people's traits and behaviors.

Finally, more recent publications such as The Genesis Machine (2022) and The Coming Wave (2023) have raised questions about the opportunities and risks that open in the field of genomics in an era where synthetic biology revolutionizes not only how we define a family, but also how we respond to existential threats such as climate change, food insecurity, among others.

Background

Within the CENTRO Tomorrow Design Specialization, this article synthesizes a research project on the potential futures of genomic sequencing in Mexico. Genome research in Mexico has its roots in 1949 when the first study on the distribution of genetic markers in the Mexican mestizo population was carried out (Salamanca-Gómez, 2016). Since then, several notable projects and public policies have marked the evolution of this research in Mexico, such as the Mexican Population Genomic Diversity Project in 2009, a pioneering project in the publication of a catalog of the genetic variation of the Mexican population (Silva-Zolezzi et al., 2009). Likewise, the MX BioBank Project managed in 2017 to obtain the DNA profile of more than 6 thousand individuals from the 32 states of the Mexican Republic (Sohail et al., 2022, 2023). Also, after two years of the pandemic, the National Council of Humanities, Sciences, and Technologies (CONAHCYT) collaborated with the Mexican Consortium of Genomic Surveillance (CoViGen-Mex) to carry out 12 million genomic sequences of SARS-COV2 and obtain 72 thousand genomes of this virus to contribute to public health prevention (National Council of Science and Technology, 2022).

Another noteworthy public policy in Mexico is the oriGen Project, a unique project in Latin America launched by the Mexican private university Tecnológico de Monterrey in collaboration with the National Institute of Genomic Medicine (INMIGEN) in December 2022 to have a database of genetic information of at least 100,000 Mexicans to improve preventive and accurate health in Mexico (Irais, 2022).

Mexico's role in shaping the future of human genome research has some key players charting the way forward in developing this technology and its applications. Among the key players are institutions such as Genómica Médica, a private entity pioneer in human genomics in the country; the previously mentioned INMEGEN, founded in 2004 to promote the evolution of genomic medicine in the Mexican population; the National Genomics Laboratory for Biodiversity in Mexico (LANGEBIO), a laboratory associated with the Center for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV-IPN) since 2005 and home to eminent international researchers in the field; and the Center for Genomic Sciences (CCG), which brings together a team of researchers in laboratories specializing in microbial and plant genomics. These entities, together with the critical role to be played by public policymakers in genomic sciences, are the pillars that will be able to shape the genomic sequencing landscape in Mexico by the year 2035.

Genomic sequencing: Opportunities and challenges

Genomic sequencing, a laboratory technique aimed at determining the precise arrangement of nucleotides or bases in a DNA molecule (commonly referred to as A, T, C, and G), plays a crucial role in understanding the function of genes and the human genome (National Human Genome Research Institute, 2023). This knowledge has led to significant advances in the field of personalized medicine (Lightbody, 2019; Roychowdhury, 2020; Agendia, 2018), early diagnosis of diseases (Hernández et al., 2020; Comas & Gil, 2016; De Salazar et al., 2021), and plant and crop breeding (Sun et al, 2022; Wang & Han, 2022; Pazhamala et al, 2008), to name a few. Despite these benefits, the development of genomic sequencing and its applications face social, economic, political, ethical, and regulatory challenges. One of the critical points is the bioethical issue and the lack of governmental support. In Mexico, public investment in genomic medicine is limited due to the need for more political interest (Gunn, 2023). Likewise, authors such as Casero (2001) and Sardi Dima (2020) highlight the risks of discrimination associated with misusing genetic sequencing. Cifuentes et al. (2022) emphasize the importance of protecting the privacy of genetic data, while Bergel (2017) points to the ethical debate over techniques such as germline gene therapy or "improvement"

interventions, and controversial treatments that stem from genomic sequencing.

In the context of human genome legislation, it must be noted that in Mexico lags other countries, as noted by Méndez (2022). This regulation gap is not innocuous, as it underscores potential future risks linked to the ethical and legal challenges that may emerge from upcoming development in the field. Table 1 provides an overview of the existing legal framework, including key overarching regulations such as the General Health Law and the Federal Criminal Code, which address issues like the prohibition of discrimination on genetic grounds and the crime of gene manipulation. Additionally, relevant laws include the organic statutes of INMEGEN and a Federal Decree creating the National Bioethics Commission and the Law on Biosafety of Genetically Modified Organisms.

Table 1. Legal Framework on the Human Genome in Mexico

Legal System of Human Genome in Mexico
General Health Law Fifth A: The Human Genome Single chapter Article 103 Bis 2. No one may be subjected to discrimination, rights infringement, freedoms or dignity because of his genetic characteristics. The Human Genome may not give rise to pecuniary benefits, nor may it be the object of patents. Article 103 Bis 3. Any study in this field must have the express acceptance of the person subject to the study or his/her legal representative regarding the applicable legislation. The confidentiality of the genetic data of any group or individual, obtained or kept for diagnostic and preventive, research, therapeutic, or any other purpose, must be safeguarded in the handling of the information, except in cases where there is a court order.
Regulations of the General Health Law on Health Research Title Five Internal Committees in Health Institutions ARTICLE 99.- In every health institution where health research is carried out, under the responsibility of the respective directors or heads and by the applicable provisions, the following shall be constituted: I. A Research Ethics Committee if they research human beings; Fraction amended DOF 02-04-2014. II. A Biosafety Committee determines and regulates the use of ionizing radiation or genetic engineering techniques within the institution based on the applicable legal provisions and Fraction reformed DOF 02-04-2014. III. An Investigation Committee, whose integration will be mandatory for the institutions providing patient care. health
Science and Technology Law It establishes that "The [government] support instruments shall not affect the freedom of scientific and technological research, without prejudice to the regulation or limitations that for reasons of safety, health or ethics or any other cause of public interest may be determined by legal provisions."
Federal Criminal Code Chapter Three Biosafety A prison sentence of one to nine years and a fine of three hundred to three thousand days will be imposed on anyone who, in violation of applicable regulations, introduces into the country, or extracts from it, trades, transports, stores, or releases into the environment, any genetically modified organism that alters or may negatively alter the components, structure or functioning of natural ecosystems.
Organic Statute of the National Institute of Genomic Medicine GENERAL PROVISIONS The National Institute of Genomic Medicine is a decentralized body of the Federal Public Administration [...] whose purpose, in the field of genomic medicine, is scientific research, education and training of specialized human resources, development of technology, and linkage with industry for the development of genomic-based products and services, and whose scope of action includes the entire national territory.
Decree that creates the Decentralized Body called the National Bioethics Commission. Among is functions includes: “To propose to the Secretary of Health the public health policies related to bioethics and [...] IV. To promote ethical principles and foster non-discrimination and gender equity in the National Health System.”
Genetically Modified Organisms Biosafety Law CHAPTER 1 Object and purpose This Law is of public order and social interest. Its purpose is to regulate the activities of confined use, experimental release, pilot program release, commercial release, commercialization, import, and export of genetically modified organisms, to prevent, avoid or reduce the possible risks that these activities could cause to human health or the environment and biological diversity of animal, plant and aquaculture health.

Methodology

This study employed foresight techniques to synthesize the complex body of knowledge describing the future implications of genome sequencing. The knowledge base was gathered through extensive desk research conducted from 2018 to 2023 in Mexico City as part of the Design of Tomorrow Specialization Program at CENTRO. The foresight framework and methods were chosen to unpack the topic's complexity, moving from broad to specific insights and from problem identification to envisioning a desired future state.

Part 1 of the study focuses on contextualizing the landscape of genome sequencing in Mexico with interviews and horizon scanning.

Part 2 consists in identifying and visualizing the driving of change through the Futures Triangle technique.

Part 3 develops contrasting scenarios based on critical uncertainties using a 2x2 Matrix.

Part 4 examines deeper systemic and meta-narrative elements beyond the surface of genome sequencing technicality using Causal Layered Analysis (CLA).

Together, these approaches facilitate a comprehensive exploration of potential futures and identify key leverage points for strategic intervention. The specific application and value of each method are detailed below.

Part 1

1.1 Interviews with experts

The research included interviews with four professionals and experts on Genomics in civil society, private companies, and research bodies immersed in subfields such as bioethics, personal information, DNA sequencing and personalized genetic medicine. These interviews aimed to explore diverse perspectives on the future of genomic sequencing in Mexico. The technique allowed us to obtain a broad view, thus contributing to a complete understanding of how various experts perceive and understand the object of study.

Table 2: List of experts consulted

Expert 1	Civil society data analyst with extensive experience in personal information management.
Expert 2	CEO and researcher in a start-up company in preventive and personalized genetic medicine with skills in developing methodologies for genetic medicine.
Expert 3	Researcher in a private company specializing in DNA sequencing; experience in advanced genetic sequencing techniques.
Expert 4	Bioethicist expert in ethical dilemmas in genetics and biotechnology.

1.2 Horizon Scanning:

The research also included elaborating a Horizon Scanning where 189 signals of change and trends related to the future of genomic sequencing in Mexico were mapped. The following are the key emerging themes:

- Research and advances in genomics (42% of signals/trends): Including genetic studies, precedent-setting discoveries in the field of genomics, and advances in genetic knowledge.
- Collaborations and technological developments in genetics (17%): Focusing on technological developments in genetic sequencing, collaborations between institutions and companies, and advances in genetic methods and tools.
- Medical and therapeutic applications of genomics (18%): Addressing issues related to personalized medicine, gene therapies, and the use of genomics in medical treatments.
- Ethical, social, and Legal aspects of genomics (15%): Considering ethical issues, social impact, and legal aspects of genetic research and its application.
- Genetics education and outreach articles (6%): Including educational resources, outreach articles, and efforts to increase public awareness and understanding of genetics.

Case studies and specific discoveries (2%): Articles and research products that focus on situations, unique cases,

or specific discoveries that do not necessarily represent general trends or broad applications but provide valuable or novel information in their field.

The interviews and Horizon Scanning insights are available upon request. To protect participants' identities and comply with data privacy regulations, all identifying information has been anonymized or omitted.

The data from Interviews and Horizon Scanning (Part 1) is further analysed and systematized by the authors through the Futures Triangle (Part 2).

Part 2: Futures Triangle

A Futures Triangle was applied to structure drivers of change and signals gathered through Horizon Scanning and interviews. The methodology offered a comprehensive map of forces shaping genomics in Mexico. This step of the analysis helps to clarify both constraints and aspirations, providing a foundation for the next part of the study in the 2x2 Scenario Matrix.

Part 3: 2x2 Scenario Matrix

The 2x2 Matrix, a technique developed by Jay Ogilvy and popularized in the *Art of the Longer View* (1991) by Peter Schwartz, was adopted to select two high-impact, high-uncertainty variables—genomic sequencing cost and ethical regulation—as axes for a 2x2 matrix, yielding four distinct scenarios based on variable combinations. This framework facilitated the exploration of plausible futures, guided scenario narratives, and tested scenario robustness under uncertainty.

Part 4: Causal Layered Analysis

Causal Layered Analysis (CLA) was used to uncover the meta-narratives behind the best and worst scenarios, highlighting core issues like genetic data privacy, discrimination, and social equity (Inayatullah, 2004). By surfacing these underlying perspectives, it revealed mindsets and narratives shaping genomics acceptance, enriching scenario backstories and contextual implications.

Results

Figure 1 presents the analysis using the Futures Triangle. The Push of the Present covers the current trends in genomic sequencing such as the significant decrease in costs associated with this technology, the increasing development of innovative sequencing methodologies, as well as the increasing integration of technological advances such as Artificial Intelligence (A.I.). In addition, new models of personalized medical care are mentioned, as well as the notorious increase in public awareness of the importance of health.

The Pull of the Future projects the potential future images that tend to permeate the collective consciousness in a world where advanced applications of genomic sequencing are a reality: improvements in public health through proactive disease identification and treatment, medical care that is tailored to individual needs promoting better quality of life and optimization of healthcare resources, and expanded knowledge of family health history that drives the adoption of preventive behaviors among individuals.

The Weight of the Past highlights factors categorized as the main obstacles that could inhibit or strongly shape the evolution of genomic sequencing in Mexico. The influence of social norms, values, and attitudes around genome studies and technologies, economic constraints that limit the allocation of funds in this area, and the absence of a robust regulatory framework on privacy and genetic confidentiality are highlighted.

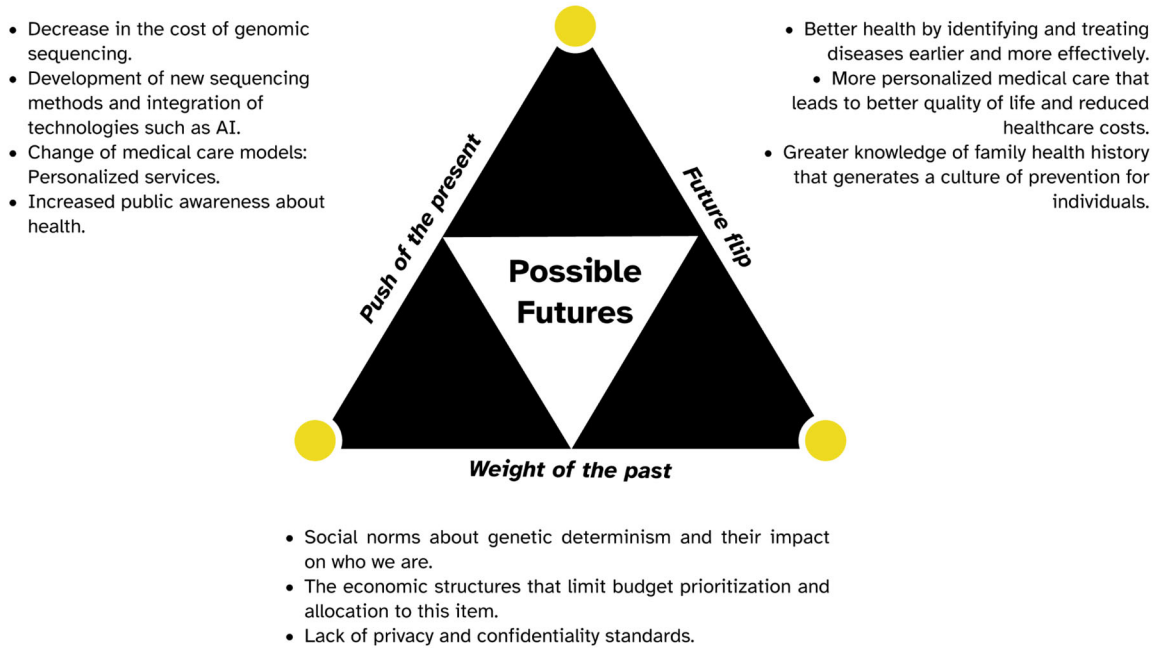

Fig. 1: Futures Triangle of Genomics Adoption in Mexico.

Four Scenarios of Genomics in Mexico by 2040

Based on the findings of the Futures Triangle, four alternative scenarios were elaborated using the 2x2 Matrix. These scenarios are not intended to predict the future of genomic sequencing in Mexico but rather to offer multiple visions and implications for developing this technology in Mexico. The two critical uncertainties derived from Part 1 & 2 of the analysis include:

- Genomic Sequencing Cost: It is the price associated with the process of completing the DNA sequence of an organism, influenced by the technology used and the complexity of the genome.
- Genomic Sequencing Ethics: Refers to the contextual moral considerations related to privacy, consent, use, and handling of genetic information obtained by sequencing.

Figure 2 presents the 2x2 matrix framed by the two critical uncertainties: Genomic Sequencing Cost and Genomic Sequencing Ethics:

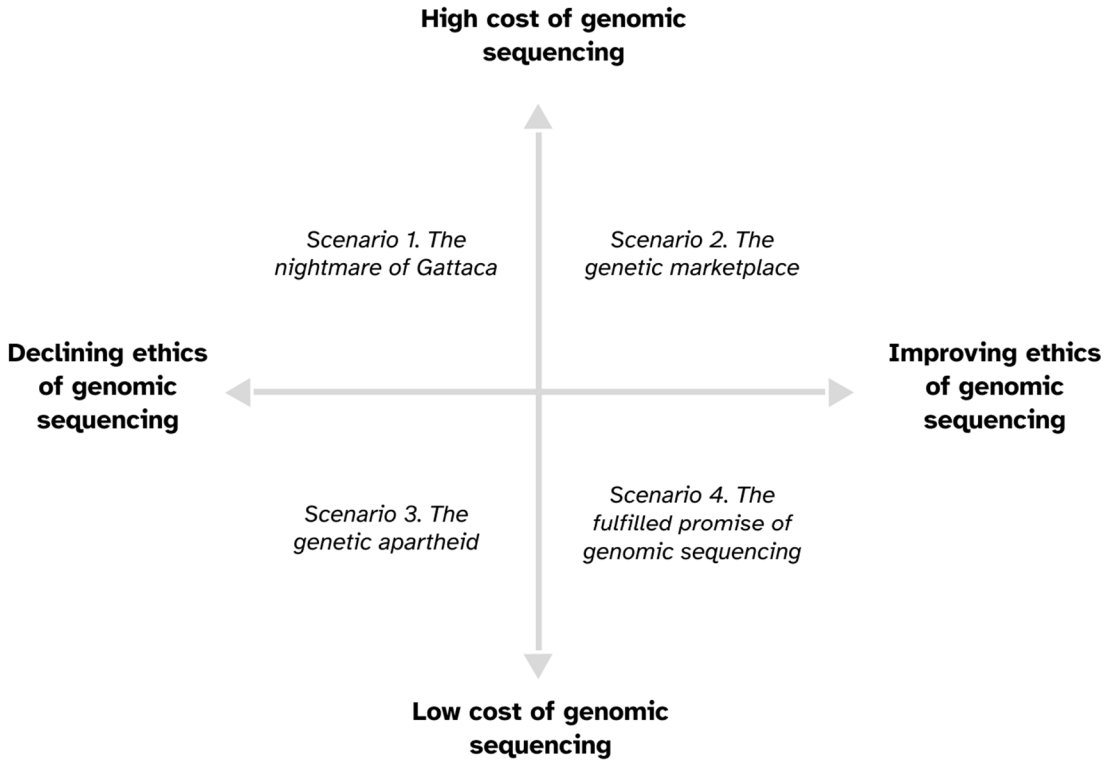

Fig. 2: 2x2 Matrix of Genomic Sequencing in Mexico.

Scenario 1: The Nightmare of Gattaca

In Mexico City in 2035, Luna, a middle-class young woman, acquires a false genetic identity to work at the elite GenMex consulting firm in the Templo Mayor Tower. Although brilliant, Luna's secret is soon discovered and fired after being subjected to a random genetic sequencing test. The scandal transcends nationally and opens a debate on genetic discrimination in the workplace in an era dominated by advanced biotechnology.

This is a world in which genomic sequencing has become a luxury technology for a privileged few due to its high cost. Likewise, genomic sequencing is the most desired tool for companies to make decisions based on the genetic profile of applicants. Critical public policy decisions and corporate strategies are made based on the genetic background of those who apply, thus determining the immediate denial of benefits to those who cannot afford a genomic sequencing test. This unscrupulous use of genomics has created a profound social, ethical, and racial problem.

An individual's potential and value are measured by his or her genetic code. “Genetic ghettos" emerge as segregated communities that divide individuals according to their genetic profile classification: "ideal," "conflicting," or "unknown." These segregated communities determine the supply of employment and recreational opportunities available to the population.

Scenario 2: The Genetic Marketplace

Genomic sequencing is used to diagnose diseases, develop treatments, and improve overall health. However, the cost of genomic sequencing remains high, limiting its availability to many people and creating a gap between those who can and cannot afford this technology.

Despite the cost, the ethics of genomic sequencing have become an important issue. There is growing concern about the negative potential for this technology to become a discriminatory tool, for example, by denying employment or access to a benefit based on the genetic data obtained.

Several ethical standards for genomic sequencing have been developed to address these concerns. A recent milestone was the implementation of the "Genome Law" that stipulates high monetary penalties for those who practice genetic employment discrimination and further empowers the National Institute for Access to Information, Transparency and Data Protection (INAI) with the task of monitoring and guaranteeing the privacy of individuals' genetic information when receiving employment and government support.

One of the most important ethical principles behind the Genome Law is autonomy, which establishes that people have the right to decide whether to undergo genomic sequencing when receiving a medical diagnosis or applying for any benefit. Likewise, the law grants citizens the right to receive information on their genetic results, to keep their genetic data protected, and not to be discriminated against or receive different treatment if they decide to share their genetic information.

Ethical standards continue to evolve, seeking a balance between technological progress and human rights. Respecting autonomy and non-discrimination, the aim is for genomic sequencing to be a tool for collective well-being, not for generating new forms of inequality.

Scenario 3: The Genetic Apartheid

Genomic sequencing, now more accessible due to cost reductions, has expanded beyond medicine, from disease diagnosis and treatment to mate selection based on genetic compatibility and optimization of biological traits. However, this democratization of technology has also brought with it significant ethical challenges, including making genetic sequencing studies mandatory in all areas of public life.

Genetic discrimination has become an increasingly prominent problem. Taking advantage of their applicants' genetic information, insurance companies have begun to deny coverage or impose exorbitant premiums based on genetic risk profiles. Employers, for their part, use this data to influence hiring, promotion, and firing decisions, creating a deeply segregated labor market. Governments distribute social assistance based on genetic algorithms that autonomously decide who is and is not eligible for support.

The mandatory practice of genomic sequencing in the public sphere has led to a new social stratification based on genetic profiles that divide society and create a form of "genetic apartheid": those who have a "desirable" genetic profile and those who do not. This violates human rights and prevents many people from reaching their potential, limiting their access to employment and health opportunities.

Recent events, such as the "Genome-X Project" controversy, where the illegal sale of genetic data to third parties was revealed, have unleashed protests in Mexico's main cities. In addition, the emergence of exclusive "genetic clubs," which promote the union of people with "desirable" genetic profiles, has exacerbated practices of social exclusion.

In response to this crisis, several solutions have been proposed. Civil society organizations are promoting legislation to prohibit the use of genetic sequencing at a time when Mexico is experiencing one of its deepest social polarizations marked not only in the realm of ideas but also in the differentiated physical and human development of Mexicans.

Scenario 4: The Fulfilled Promise

The cost of genomic sequencing has fallen so low that it has become one of the most revolutionary technologies of the 21st century. A transformation in healthcare has occurred, allowing people to access information about their health and genetic risks that were previously unavailable.

Genomic sequencing is used to diagnose diseases, develop new treatments, and improve preventive health. For example, it can be used to diagnose and predict diseases in advance or to identify individuals at increased risk of disease and adopt treatments without invasive procedures.

The affordable cost and widespread availability of genomic sequencing have profoundly impacted health and have extended to other areas, such as biodiversity and crop improvement, benefiting not only humans but also

animals, plants, and ecosystems.

A notable development of the Mexican government is the Program "Genome for All", an initiative that facilitates free genomic testing for underserved populations, ensuring equity in access to health care. In addition, with advice from the National Institute of Genomic Medicine and civil society organizations, the Mexican Congress has passed significant legislation to ensure ethical and responsible use of genetic data. With the continuous evolution of technology, a future is anticipated where personalized medicine and disease prevention are a reality accessible to all.

Summary of scenarios

The Four Scenarios of Genomics in Mexico by 2025 are summarized in Table 3, it highlights the dynamics of multiple driving forces of change (including genomic sequencing costs, ethics, accessibility, usage, legal aspects, social implications, and healthcare impacts) across different scenarios.

Table 3: The Four Scenarios of Genomics in Mexico 2035.

Key variables	**Scenario 1: The nightmare of Gattaca**	**Scenario 2: The genetic marketplace**	**Scenario 3: The genetic apartheid**	**Scenario 4: The Fulfilled Promise**
Genomic sequencing cost	High	High	Low	Low
Genomic sequencing ethics	Genetic discrimination, social stratification, and reduced privacy	Privacy standards and responsible use of genetic data	Genetic discrimination, social stratification, and reduced privacy	Privacy standards and responsible use of genetic data
Technology accessibility	Limited to privileged few	Limited to those who can afford it	More accessible to the public	Widely accessible
Genomic sequencing usage	Employment decisions, social stratification	Disease diagnosis, treatment, employment decisions	Mandatory in public life, insurance, employment, social assistance	Healthcare, biodiversity, crop improvement
Legal/policy framework	Underregulated	Genome Law with penalties for discrimination, privacy protection	Proposals for legislation to prohibit genetic sequencing usage	Legislation for ethical implementation and universal use

Social implications	Genetic ghettos, employment segregation	Concerns about discrimination and privacy	Genetic apartheid, social exclusion, protests	Equity in healthcare, accessible personalized medicine
Healthcare impact	Limited to privileged few, social segregation	Limited due to high cost	Segregated access based on genetic profiles	Revolutionary, predictive, and preventive health benefits

The Desired Future

To create a compelling image of the desired state of the future, Causal Layered Analysis (CLA) was employed to synthesize the visions of the interviewed experts, and the most innovative findings of the horizon scanning process. This process was applied to the least favorable scenario (The Nightmare of Gattaca) and the ideal scenario (The Fulfilled Promise).

CLA analysis revealed two contrasting narratives outlining Mexico's divergent genomic futures:

In the least favorable scenario ("The Nightmare of Gattaca"), genomic sequencing becomes a tool that deepens social inequalities. At the surface level (litany), genomic sequencing remains inaccessible to most of the population, widening the gap in health services and fostering public disillusionment with healthcare innovation. The systemic causes reveal persistent technological and economic barriers, combined with stagnant policies that fail to support necessary education and infrastructure. This scenario is underpinned by worldviews that maintain a reactive rather than proactive approach to health, devaluing preventive medicine and genomic innovations. At the deepest level, the metaphorical narrative echoes 'Jurassic Park', where uncontrolled genetic advancement leads to unpredictable and potentially dangerous societal consequences, highlighting fears about the misuse of genetic technology.

In the most favorable scenario ("The Fulfilled Promise"), genomic sequencing becomes a catalyst for healthcare democratization. The litany shows genomic sequencing becoming affordable and integrated into standard healthcare, enabling personalized medicine and improved health outcomes for the general population. Systemically, this is supported by evolved economic strategies and policies that actively promote genomic education and infrastructure development. The worldview shift demonstrates a society that embraces preventive health measures, with genomic sequencing recognized as an essential component of healthcare. The metaphorical narrative transforms to reflect an 'In Time' scenario, where ethical integration of genomic technology creates a more egalitarian society, ensuring genetic benefits are accessible to all, not just the privileged few. This future represents a fundamental shift from genetic information as a source of discrimination to a tool for health equity.

Figure 3 provides a summarized breakdown of how these scenarios unfold across the four layers of CLA analysis—litany, systemic causes, worldviews, and myths & metaphors—comparing the present situation with both resolved and unresolved future states.

CLA Layer	Present	Future without Problem Resolution	Future with Problem Resolution
Litany	The high cost and inaccessibility of genomic sequencing are prominent issues, making it a luxury rather than a standard healthcare service available to the general population.	Genomic sequencing remains out of reach for most, with inequality in health services increasing. This may lead to public discontent or resignation regarding health innovation.	Genomic sequencing becomes affordable and integrated into standard health care, leading to personalized medicine and improved health outcomes.
Systemic	Current economic and technological limitations, alongside policy and educational gaps, contribute to the underutilization and inaccessibility of genomic sequencing.	Persistent technological and economic barriers prevent the widespread adoption of genomic sequencing. Policies remain unchanged, and investment in related education and infrastructure is lacking.	Economic strategies and technological advancements make sequencing more accessible. Policies evolve to support genomic education and infrastructure development.
Worldviews	There is a prevailing perception that genomic sequencing is not an immediate health priority compared to other health challenges, and there may be cultural resistance or lack of understanding of its benefits.	Cultural and societal norms continue to devalue preventive medicine and innovations like genomic sequencing, maintaining a reactive rather than proactive health system.	The cultural perception shifts to value preventive health measures, with genomic sequencing being understood and accepted as a vital component of health care.
Myths & Metaphors	Current fears about genetic sequencing mirror societal stratification seen in 'Gattaca' (Andrew Niccol, 1998), where genetics determine one's societal status, raising concerns about privacy, discrimination, and the ethical use of genetic data.	Persistent myths could evolve to reflect a 'Jurassic Park' (Steven Spielberg, 1993)-like scenario where unchecked genetic advancements lead to unpredictable and potentially dangerous societal consequences, mirroring the film's unintended outcomes of resurrecting dinosaurs.	In a resolved future, the narrative could shift to an 'In Time' (Andrew Niccol, 2011) scenario, where ethical integration of genomic technology into society leads to increased healthspan and a more egalitarian society, reflecting a world where genetic benefits are accessible to all, not just the privileged few.

Fig. 3: Causal Layered Analysis on the Present, Worst and Best Scenario of Genomic Sequencing in Mexico

Conclusions

This research allows us to identify the potential of foresight applied to genomic sciences to anticipate the implications in the public and private life of emerging technologies arising from genomic sequencing. Through Futures methodologies such as the Futures Triangle, the development of 2x2 Matrix, and Causal Layered Analysis, it is possible to structure, analyze, and explore the possible futures of highly complex issues such as those addressed here. The aim is not to predict the future but to anticipate the wide range of possibilities that are opening around genomic sequencing. It also provides practical frameworks for Mexican policymakers developing genomic privacy regulations and healthcare institutions planning genomic service integration. It contributes to literature by being among the first to apply multiple foresight methodologies to genomic sequencing in Mexico, offering unique insights on balancing technological access with ethical governance in developing nations. The combination of Horizon Scanning with expert interviews demonstrates a novel approach to analyzing emerging genomic trends within specific cultural and economic contexts.

As we move into the future, it becomes evident that numerous critical challenges and disruptive forces are poised to shape the narratives of the alternative scenarios. These encompass the rapid advancements in Artificial Intelligence, which are revolutionizing genomic data analysis and interpretation, data privacy regulations adapting to the intricacies of genetic information handling, and the ongoing ethical deliberations concerning genome editing, genetic privacy, and equity in genomic healthcare. Further research, building upon this foundation, can delve deeper into how these key elements will intricately shape and redefine the proposed scenarios, offering invaluable insights

for policymakers, scientists, and stakeholders in the field of genomics.

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